Volume 14 MARCH 1930 Number 3

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## *of the*
# American Association *of* Petroleum Geologists

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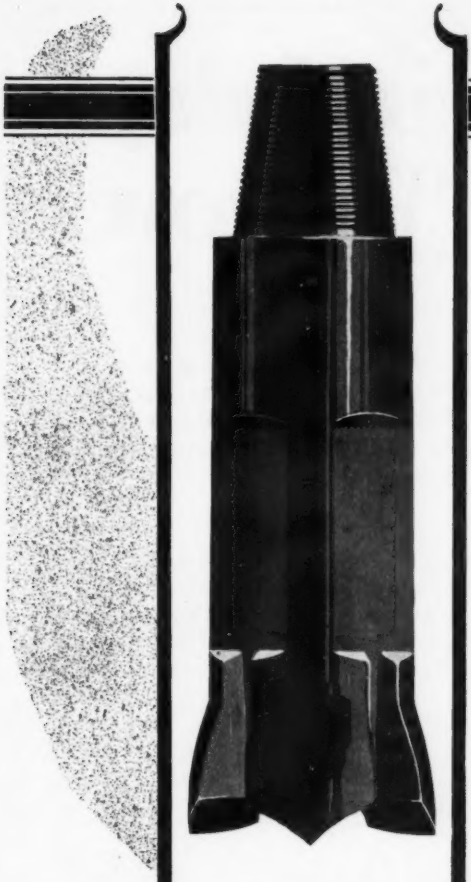

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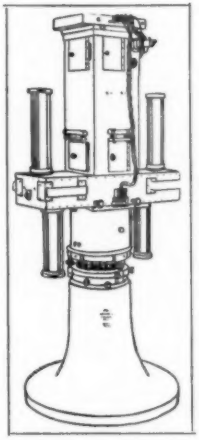

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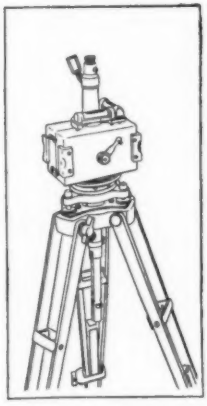

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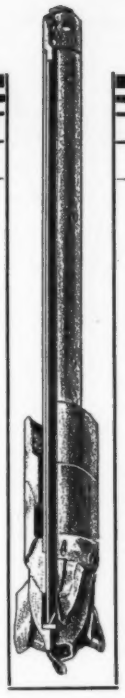

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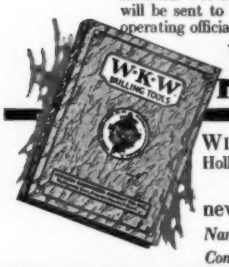


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Volume 14 Number 3

BULLETIN

*of the*

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

MARCH 1930

# GEOLOGY OF SOUTHWEST ECUADOR[1]

GEORGE SHEPPARD[2]
Guayaquil, Ecuador

## ABSTRACT

The general geology of southwest Ecuador is described. The area is approximately 140 miles north and south, and 90 miles east and west, lying south of Manta and northwest of Guayaquil and the mouth of Rio Daule. The formations include Tertiary sediments and igneous intrusions. The writer attempts particularly a study of the geology north and east of the Cordilleras de Colonche and a correlation of these formations with those farther south. Observations of structural and depositional conditions are presented. The paper is illustrated by a map of the areal geology, columnar and cross sections, and microscopic slides.

## INTRODUCTION

The observations recorded in the following pages are the result of various expeditions made into the provinces of Manabi and Guayas during the last few years. They are published through the courtesy of the Anglo-Ecuadorian Oilfields, Ltd. An attempt has been made to ascertain the nature of the geology in the region north and east of the Cordilleras de Colonche, and to correlate, if possible, the geological formations of the province of Manabi with those already studied in the Santa Elena region on the south. Acknowledgments are duly made to authors of previous works; also to L. W. Berry, C. Barrington Brown, and A. J. R. Murray, for valuable unpublished reports.

[1]Manuscript received by the editor, December 24, 1929.

[2]State geologist, Republic of Ecuador.

## TOPOGRAPHY

Before dealing with the special features of topographical interest which are found in this region, it is necessary to explain that, although the underlying structure of the geological formations was the factor which initiated the existing relief of the country, it is also probable that recent denudation, caused by intermittent periods of excessive rainfall since the close of the Quaternary, has had a greater effect upon the sculpturing of the land surface.

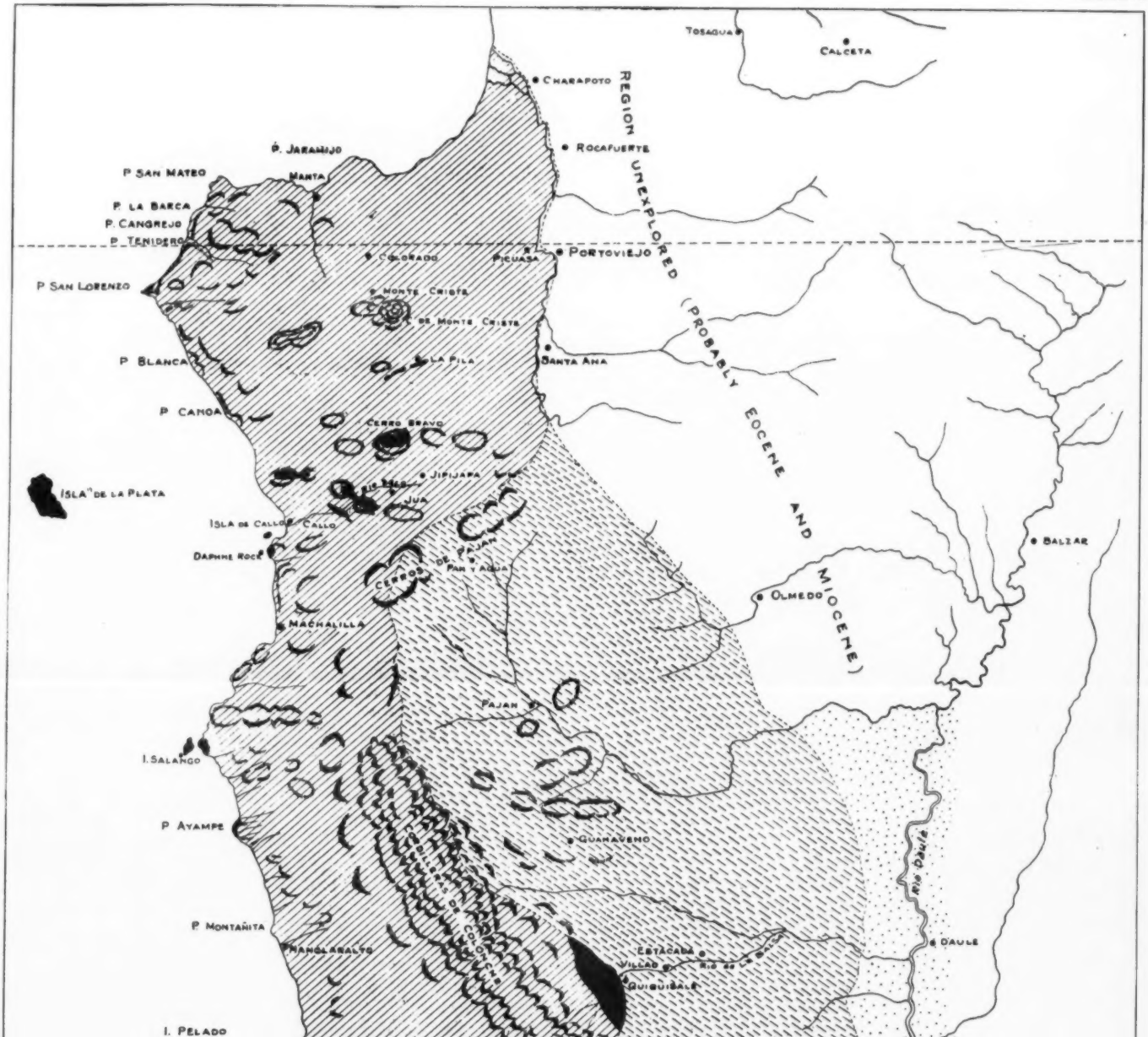
By the rejuvenation of the rivers, and by periodic changes in their respective courses, sharply defined escarpments and valleys have been formed; as a general result the aspect of the present topography is of a highly complicated and irregular order. The principal topographical units can be described conveniently under the following headings: (1) the Cordilleras de Colonche, (2) the basin of Rio Daule, (3) the region east of the Cordilleras de Colonche and north toward Pajan and Jipijapa, (4) the district between Jipijapa and Callo, (5) the Monte Cristi region, and (6) the coastal sections (Plate 1).

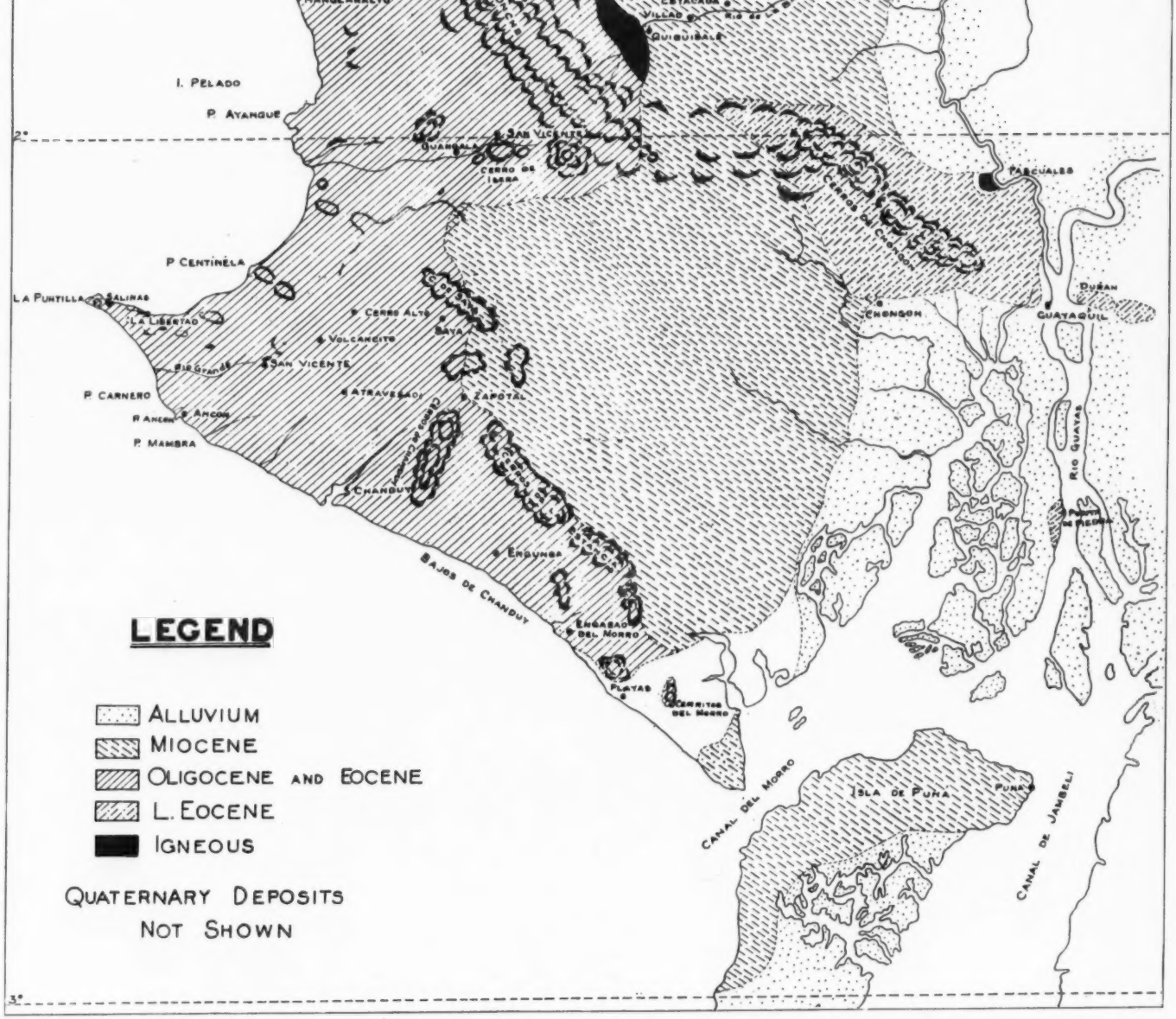
### CORDILLERAS DE COLONCHE

This prominent range of hills forms the principal divide in this part of the country, and rises to an estimated height of nearly 2,000 feet above sea-level. Topographically, the range forms part of the same uplift as the Cordilleras de Chongon, though the latter may include older geological formations. The Cordilleras de Colonche have a width, from southwest to northeast, of approximately 25 miles, and consist entirely of shales and sandstones which, in the absence of fossil evidence, are tentatively ascribed to the Tertiary. They are flanked on the east by a series of igneous intrusions.

The Cerro de Isera, an outstanding peak of chert near the village of Guangala, forms the beginning of the Cordilleras proper, though hills of lesser elevation are found east of Colonche. The eastern slopes of the hills are densely wooded, a feature which is in striking contrast to the westerly flanks of the same range. Three prominent ridges, the highest occurring on the east, form the central Cordilleras; thence eastward the land surface gradually decreases in elevation toward the settlement of Villao, which is about 250 feet above sea-level (Fig. 1).

The intervening country, defined by the divide on the west and by the village of Villao on the east, consists of gently rolling plains with few ridges, and is underlain by igneous rock of a basic, hypabyssal type.


TOSAGUA
CALCETA
CHARAPOTO
REGION UNEXPLORED (PROBABLY EOCENE AND MIOCENE)
ROCAFUERTE
P. JARAMIJO
P SAN MATEO
MANTA
P. LA BARCA
P. CANGREJO
P. TENIDERO
COLORADO
PICUASA
PORTOVIEJO
P SAN LORENZO
MONTE CRISTO
DE MONTE CRISTO
P BLANCA
LA PILA
SANTA ANA
P CANOA
CERRO BRAVO
JIPIJAPA
ISLA DE LA PLATA
RIO SALO
JUA
ISLA DE CALLO
CALLO
DAPHNE ROCK
CERROS DE PAJAN Y AGUJA
BALZAR
OLMEDO
MACHALILLA
PAJAN
I. SALANGO
P AYAMPE
GUAYAQUIL
P MONTAÑITA
MANGLARALTO
ESTACADA
VILLAO
RIO DE LA PLATA
QUIQUIBAL
DAULE
RIO DAULE
I. PELADO




Sketch map showing principal geological formations of southwest Ecuador. Width of area mapped, approximately 92 miles.

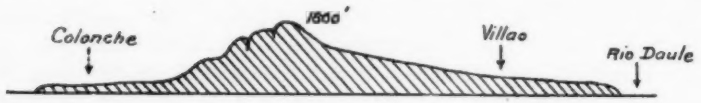



FIG. 1.—Section across the Cordilleras de Colonche. Length of section, 57.92 miles.

In this part of Ecuador, the rivers vary in size in accordance with the intensity of the respective wet seasons and the prevalence of heavy mists (locally known as "garuas"). Deep gorges have been thus eroded in the Cordilleras de Colonche, where the headwaters of many drainage channels have their origin. East of the main range the most important river is known as Rio de la Balsa, and this, with its many subsidiary streams, drains into the Daule Basin, entering Rio Daule south of the town bearing the same name. The villages of Quiquisale and Villao are situated on one of the tributaries of the same river, a plentiful supply of fresh water being present throughout the year.

### BASIN OF RIO DAULE

Rio Daule is one of the largest rivers of the Guayas system and drains an extensive region north and west of Guayaquil. Toward the south the basin is limited by the hill ranges known collectively as the Cordilleras de Chongon, which have topographical characteristics similar to those of the previously described hills near Colonche. North of these uplands the surface is comparatively flat, though slight undulations are evident toward the west. During the wet season of the year (January to April) floods are common, so extensive that swamps are ordinarily formed in the low lands near the banks of the river. With the exception of the margins of the river itself, where large deposits of alluvial mud and silt have been formed, most of the Daule Basin is underlain by Tertiary (Miocene) formations which fringe the eastern slopes of the Cordilleras de Colonche and extend northward almost as far as Jipijapa.

### REGION EAST OF THE CORDILLERAS DE COLONCHE AND NORTH TOWARD PAJAN AND JIPIJAPA

From Villao eastward to Estacada, the land surface is gently undulating, well wooded, and in places covered with thick vegetation. Northward, however, the general aspect changes and the Cordilleras de Colonche seem to terminate abruptly as a topographical unit. Although the territory adjacent to the coast line is distinctly hilly, with irregularly disposed escarpments and groups of low ranges, it is improbable that

these elevations form part of the same history as the Cordilleras de Colonche proper. Near the settlement known as Cruz de Guanaveno, the country assumes a distinctly tropical appearance, with dense vegetation and jungle covering all the hill ranges. This condition continues almost as far as Jipijapa, where a change to semi-arid vegetation is noticeable.

The most conspicuous feature between Guanaveno and Pajan is a regularly disposed escarpment facing southwest. It rises to a height of about 500 feet above the valley, and extends nearly 8 miles in a generally northwest direction. This escarpment is made up of Miocene sandstones and shales, and at its base are low foothills which have been formed by the slipping of detached blocks of sandstone from above.

The southerly slope of this ridge is covered with thick vegetation, and is drained by many small streams which have excavated relatively deep valleys. The heavy mists which ordinarily form near the summit of this range are the chief source of the many springs which issue from the upper formations.

The Cerros de Guanaveno continue almost as far as Pajan, and have been dissected by river action near the town into isolated hills of a truncated form. The country appears to be distinctly hilly west of this range, a topographical condition which probably persists as far as the coast line.

On the north, beyond the settlement known as Pan y Agua and approaching Jipijapa, the country is traversed by several ranges of hills, or irregular escarpments, which demonstrate the nature of the geological structure of the formations beneath. It is known that the sedimentary formations of this region are intruded by igneous dikes and sills, these phenomena no doubt being partly the cause of the more conspicuous elevations in the topography.

### DISTRICT BETWEEN JIPIJAPA AND CALLO

The road from Jipijapa to the port of Callo follows the valley of Rio Seco, a small river which is dry the greater part of the year. In certain parts of its course, the valley assumes the nature of a gorge which has been eroded out of hard igneous rock, and in several places almost vertical cliffs have been formed which are more than 500 feet in height. It is clear that, in the past, the river which occupied this valley was of a swiftly flowing nature, the presence of igneous boulders and extensive river beaches being evidence of this earlier phase of history. A large fan of boulders transported during periods of flood is found at the river mouth and this gives an indication of the former

width of the estuary. A conspicuous hill, situated on the coast about 3 miles north of Callo, forms the beginning of a series of similar uplands in the vicinity of Rio Seco, these gradually increasing in height toward the interior. The hill referred to is of igneous origin, and probably marks the western extremity of the igneous outcrops which are seen in the valley of Rio Seco at the present time.

Near the settlement of Jua, about 3 miles west of Jipijapa, a small spring of water impregnated with sulphuretted hydrogen issues from a valley which is drained southward. In all probability this spring has its origin in the volcanic formations which make up Cerro Bravo and, judged by the nature of the ejected igneous rocks, tuffs, and ash, there is good reason to suppose that this high peak was an active volcano in the past, its contour even now being that of a typical crater. Among the rocks associated with this volcanic center are certain lavas, with porphyritic types, which are found in the main valley near Jua. Both Jua and Jipijapa are situated in what appear to have been temporary lake basins in the main valley, and owe their origin to large quantities of gravel and other detritus brought down by tributary streams. Well marked terraces are also a feature of these basins.

### MONTE CRISTI REGION

The prominent volcanic hill known as the Cerro de Monte Cristi forms the most important topographical unit of this region. It rises to a height of nearly 1,800 feet above sea-level and appears as a defined landmark for many miles, contrasting sharply with the low-lying plain which consists of a level Quaternary formation. During Quaternary time the Cerro de Monte Cristi formed an island in the ocean, but later it became part of the mainland as a result of the post-Quaternary uplift of this section of the coast belt. Near the foot of the hill, at the town of Monte Cristi, is a series of loose terrace deposits consisting entirely of detrital material carried down from the adjacent slopes by local flood and stream action. This débris includes volcanic rock of a black, andesitic type which has gravitated from the hill itself, and light-colored shales and sandstones which also form part of the Tertiary group of sediments occurring beneath the Quaternary.

The Cerro de Monte Cristi marks the beginning of a series of hills which can be followed south almost as far as Jipijapa, thence west toward Punta San Lorenzo and Callo. The principal ridges are more than 1,000 feet in height and seem to follow a northeasterly trend. Although some

of these topographical scarps are formed by highly inclined blocks of Tertiary sandstone, the factor of known igneous intrusions must also be taken into account. Near the settlement of La Pila, about 3 miles south of Monte Cristi, one of these igneous dikes is exposed in a general northeasterly trend. Several ranges of hills, however, consist entirely of Tertiary shales which seem to be quite unaltered lithologically, a fact which suggests that the metamorphic effect of the dikes is purely local. The natural low areas between the respective ranges are ordinarily occupied by fans of redistributed silt or alluvium, these deposits having been accumulated during severe rainy seasons in the past. With the exception of these deposits, and the extensive Quaternary tablazo found from Manta south to Monte Cristi, all the sedimentary formations of this area are Tertiary in age.

### COASTAL SECTIONS

The coast line in the vicinity of Manta presents little of extraordinary interest except the Quaternary terraces, which lie on the denuded edges of the more highly inclined Tertiary strata. Toward the east, one tablazo phase passes under the sea in the direction of Jaramijo, but in the opposite direction the same terrace rises to an appreciable height, and can be seen in several localities along the coast between Punta San Mateo and Punta Callo. As in the Santa Elena district farther south, there are several tablazo episodes in this northern area, representing successive uplifts of the littoral in Quaternary time. Between San Mateo and Punta la Barca, two terraces are distinctly visible on the coast, and farther inland a third appears at approximately 400 feet above sea-level. In this section the cliffs are normally low, the bluffs of Tertiary sandstone alternating with stretches of tablazo with low sandy shores. Vegetation on these slopes and along the neighboring river valleys is sparse, and consists principally of cactus and low shore growth. The topographical aspect of the shore line changes rapidly, however, between Punta Cangrejo and Punta Tenidero, as the cliffs become higher and reach an altitude of approximately 500 feet at the latter headland.

Although this point is one of the highest in this section of the coast line, a tablazo is found above the Tertiary, fallen blocks of which are seen at the water's edge. This tablazo, therefore, is probably one of the highest found on the mainland of this part of the country, and possibly corresponds with the higher tablazos found on the Isla de la Plata. The headland of Tenidero has been formed as a natural result of selective

marine erosion, the constituent formations including both hard sandstones and resistant conglomerates. Toward the south, however, the high cliffs gradually recede from the shore, and for a considerable distance the coast sections consist of loosely consolidated talus slopes persisting almost as far as Punta San Lorenzo, which forms one of the most prominent headlands on the coast of Ecuador. The headland is of igneous origin, and is fringed by small outliers in the form of islands near the shore. This igneous intrusion is probably a sill which has intruded the Tertiary sediments, the highest point of the outcrop being 400 feet above sea-level. A little farther south is the settlement of San Lorenzo, situated at the mouth of a large valley at a distance of 250 yards from the present shore line. The intervening area is actually a flat, sandy plain which at one time formed a lagoon connected with the sea.

From Punta San Lorenzo southward the coastal geography is represented by a series of bays and low headlands which have been determined primarily by the more resistant geological formations alternating with easily eroded strata, or with zones of structural dislocation. In some places, igneous intrusions form the principal headlands, as at Punta San Lorenzo and Punta Callo. Immediately south of Callo the sedimentary rocks include a series of hard conglomerates and cherts, which have a tendency to form prominent ridges or headlands wherever they occur. From the conspicuous hill north of Callo already referred to, the coast line as far as Punta Callo consists of low sandy shores with slightly higher river terraces in the vicinity of the settlement. Between Callo and Machalilla the coast sections present high cliffs of massive sandstone, overlain by white siliceous shales, these formations being block-faulted extensively in certain localities (Fig. 2).

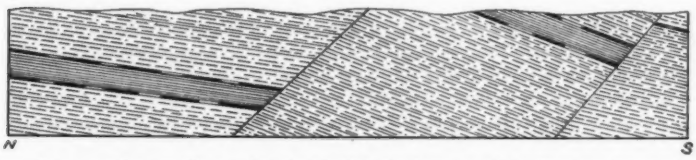



FIG. 2.—Diagram illustrating the block-faulted nature of the Tertiary formations between Callo and Machalilla.

From Machalilla, however, the trail passes inland and traverses a wide, flat valley which at one time formed a lagoon connected with the ocean. At the settlement of Lopez the beach is again followed for a short distance until a steep ascent is made up a high cliff which consists

entirely of volcanic agglomerate, or tuff. Punta Salango, Isla Salango, and Punta Ayampe are also important headlands composed of igneous rock. Punta Ayampe is also known as the Cinco Cerros, because it includes five parallel ridges of rock, truncated at the coast line, with an average height of 800 feet. From Punta Ayampe to Manglaralto the topography of the coast belt presents little of unusual interest with the exception of the headland known as Punta Montanita. This headland consists of brownish fossiliferous sandstone, and appears to be washed by the sea at all stages of the tide. Small coastal lagoons are common along this part of the coast, having been formed by the ponding back of small rivers by sand bars, or storm beaches, which are ordinarily found well above high-water mark.

### CHANDUY REGION

The settlement known as Chanduy is situated on an extensive plain from which two conspicuous ranges of hills, the Cerros de Chanduy and the Cerros de la Estancia, rise to heights of 800-1,000 feet above sea-level. The plain itself, which has an altitude of only a few feet above the sea, consists of a Quaternary tablazo upon which more recent alluvium or "wash" has accumulated from the adjacent hills. This tablazo near Chanduy covers a considerable area, as it has been recognized within a few miles of Ancon, and in all probability continues toward the east beyond the village of Playas.

Inland, the tablazo has been seen along the valley of Rio Chanduy for many miles and it probably fringes the western slopes of the hills almost as far north as Atravasado. In the wide, low area north of Engabao del Morro and Engunga the tablazo series persists almost to Zapotal.

This plain is extensively wooded with low brush and is intersected by many valleys, most of which head toward the sea. Lateral tributaries also are common, these being filled as a rule with gravelly detritus. In connection with most of the river courses of this region, it is important to notice that, although many are fairly wide, the original streams have not eroded deep gorges. All are relatively shallow, being only a few feet in depth, and most of them are filled with quartzite pebbles and denuded Tertiary sandstones. Low, rounded gravel hills are found at the foot of the Cerros de Chanduy, forming a border to the principal elevations. These hills consist of loose gravel, much of which is quartzitic. In addition, fine-grained andesite, hard conglomerate, indurated sandstone, and black-veined quartzite are common. Most of these pebbles

are about 3 inches in length, the largest rarely exceeding 6 inches. All are waterworn and rounded, indicating either transportation from a distance, or accumulation as a tidal beach. Although the quartzite pebbles are so common in this region, there is little evidence as to their original source. An examination of the slopes of the Cerros de Chanduy, however, has revealed the fact that these gravels have been derived, in post-Tertiary time, from a group of conglomerates which form the main ridges of these hills. The conglomerates ordinarily dip southeastward at a high angle, and the local sandstone in which the conglomerate is found is of a hard, massive type with little admixture of argillaceous material. The massive beds of coarse conglomerate, in which the individual pebbles consist chiefly of quartzite, form the core of the range. Toward the summit the conglomerate is replaced by a finer-textured rock which is actually a coarse grit. In these deposits, however, the larger fragments consist also of angular quartzite, possibly representing a more finely distributed stage of the conglomerate itself.

Geologically, these quartzites are very old, and during the deposition of the Tertiary along the coast belt these petrological forms must have been derived from some locality farther east where the rocks are known to be pre-Tertiary in age. Their presence, however, in the region under consideration is of great importance in the problems connected with the general conditions which governed the deposition of the Tertiary strata.

The Atravasado gravels, as they may be termed from their exceptional development at this place, are fairly widespread, and have been observed at the foot of the hill region proper, and near the villages of Saya and Atravasado. In the former location, as already mentioned, the small rounded hills and spurs near the Cerros de Chanduy are caused by direct denudation and gravitational accumulation from the conglomerate horizons in this range of hills. At Atravasado and Saya is the same series of gravels presenting the same topographical features as those already described near Chanduy.

### ATRAVASADO DISTRICT

The settlement of Atravasado is situated in a small low area, drained in the wet season by a southwestward-flowing stream, and is surrounded by low ranges, or isolated conical hills of gravel. This hill region of Atravasado probably includes an area of 15-20 square miles. The highest parts are east and northeast of the village. In common with most native settlements in this part of the country, the community

obtains water from hand-dug wells which are sunk through the river gravels of the stream courses, and reach water sands at a shallow depth. From Atravasado eastward the country is gently undulating, and all the topographical variations of the surface have been caused by superficial deposits such as gravels or recent sands. The stream courses are all shallow (trench-valleys) and only a few of the original valleys have been eroded deep enough to expose the geological formations earlier than the Quaternary. Near the village the gravels are developed to a large extent, and represent the denuded outcrop of a conglomerate of Tertiary age. North of the village, small lenses of fine sandstone are found intercalated among the gravels. In the area slightly toward the northwest the topography is modified by flat, open spaces upon which are local terrace-like deposits of Recent or Quaternary age. The deposits consist of low hills of loose beach material in which occur such forms as *Cardium*, *Turritella*, and *Arca*. It is quite possible that this series of deposits defines the northerly limit of the Chanduy tablazo which has been observed in many other localities. From Atravasado westward in the direction of San Vicente, the general aspect of the topography has been determined by the presence of an extensive tablazo plain which occurs more or less uniformly as a level terrace above the bevelled surfaces of the underlying Tertiary deposits. Unique low pampa-like areas, north of San Vicente, are defined marginally by low ranges of hills which have a general northeasterly trend. At some relatively recent period these low areas formed shallow gulfs or inlets connected with the ocean in the vicinity of San Pablo. Northwest of San Vicente the hills are capped by a small thickness of tablazo which, in this region, forms only remnants of the contemporaneous tablazo terrace which is developed more extensively toward the east, south, and west.

It is possible, however, that the history of these lagoon-like basins can be divided into two stages: (1) when they were formed as a system of river courses draining to the sea in a northerly direction; and (2) when a later inundation of the ocean caused the whole low area to be flooded in the form of a lagoon. From the evidence afforded by the denuded ridges on both sides of the basin, it is certain that the greater part of this superficial denudation was effected by river action long before the final phase occurred, during which period a shallow lagoon was formed, having a periodic connection with the ocean.

An interesting feature of the more recent drainage in this part of southern Ecuador is the presence of a low divide west of San Vicente,

where the present stream channels are diverted in two directions, southwest and north. Beneath the tablazo, however, the topography of this region is directly expressed by the geology. Here the connected ranges of hills already referred to are found. These consist of chert, hypabyssal dikes, sandstone, and shale, respectively. Although most of the rivers of this region have fairly wide valleys, their gorges are not deep. Without exception the present water-courses are dry during the greater part of the year, and have the general cross section of a trench rather than that of a normal river valley. At Volcancito, for example (north of San Vicente), the bed of Rio Grande is almost level in section, though it is possible that at some bygone time it conveyed an enormous volume of water to the sea. This activity must have been periodic only and of short duration, as nowhere has the river had either the power or the time to erode a deep gorge.

## GENERAL GEOLOGY

In a general sense, it is possible to correlate the geological formations which are found respectively in the provinces of Manabi and of Guyas. The problem, however, is one of unusual difficulty on account of the lateral differences in the sediments which have been found within comparatively short distances, also on account of the paucity of organic remains. However, certain horizons are fairly constant lithologically, a factor which makes a provisional correlation possible.

Contemporaneous volcanic activity has been the chief cause of the lithologic changes which are exemplified in so striking a manner along the coastal exposures of the province of Manabi, and it is also reasonable to assume that the large amount of volcanic detritus (dust, fragments of glass, et cetera) which has been identified in certain formations of the Santa Elena region farther south was derived initially from the same source. In addition to the centers of known volcanic eruption in Tertiary time, for example, at Cerro Bravo, near Jipijapa, an extensive series of dikes and sills was intruded later, these being closely associated with the sedimentary formations. As will be described in more detail elsewhere, most of the Tertiary sediments found in this part of Ecuador, that is, from the latitude of Manta south to the peninsula of Santa Elena, are associated with a complex system of igneous intrusions. Moreover, the pronounced variation in the sediments which has been observed in certain localities has been caused largely by contemporaneous volcanic activity. In this connection it has been noticed that most of the sedimentary formations in this region contain a fair admixture of volcanic detritus, including ash, tuffs, breccias, and conglomerates.

At a later period, also, large sills and dikes of hypabyssal material were intruded and are still found associated with the Tertiary sediments. For the purpose of comparison it may be mentioned that the white siliceous shales of the Santa Elena region (the Seca shales) are found superimposed upon a group of normal sandstones and shales which have been described as the Socorro beds.[1] The homotaxial equivalents of these beds in the north, that is, in the vicinity of Callo and Machalilla, consist for the most part of volcanic detritus, occurring in such quantity as to disguise completely the original shale or sandstone features of the formation. The highly siliceous nature of certain shales is peculiar also to this part of the coast belt of Ecuador. The presence of chert in association with igneous rocks, the tuffaceous nature of such deposits as the Ancon white sandstone, and certain lenses of white siliceous material occurring locally in many deposits have been, in the past, difficult problems to solve. Microscopic research, however, has proved that this abnormal silica content has been caused primarily by the presence of volcanic glass or dust which has been admitted into the basin of deposition during the period of sedimentation of these Tertiary formations.

The occurrence of volcanic material in the shales in the Santa Elena region (situated at some distance from a known center of volcanic activity) indicates that the principal ocean currents which bordered the coast of Tertiary Ecuador may have been directed from the north. The scarcity of organic remains in the Tertiary sediments of Ecuador, in contrast to their prevalence in the same geological formations of Peru, also may be explained by the introduction of great quantities of ejected volcanic detritus, which was no doubt fatal to the existence of many life forms. The geological formations exposed on the coast south from San Mateo toward Punta la Barca are probably of Eocene age, as certain horizons contain *Foraminifera* which are similar to those found in the known Eocene beds of the Santa Elena district. Midway between Punta San Mateo and Punta la Barca is a small headland, known as Punta Tinosa, the formations of which include sandstone beds crowded with *Foraminifera*. The eastward-dipping strata south of Punta San Mateo consist largely of tabular sandstones in addition to massive layers and local conglomerates. Though ferruginous, these sandstones contain also a fair amount of calcium carbonate, segregated into lenticular patches and forming calcareous concretions in certain horizons. In places, especially where the micro-organisms are plentiful, the beds may be

[1] G. Sheppard, "Geology of the Santa Elena Peninsula," *Trans. Inst. Petrol. Tech.*, Vol. 13 (1927), No. 62.

described as sandy limestones, and they, with the conglomerates, form the most resistant members of the series. Like the true conglomerates which occur so commonly farther south, the horizons here described have a sandy base, into which rolled volcanic rocks have been cemented (Fig. 3).

FIG. 3.—Concretion in Tertiary sandstone, southwest Ecuador.

In this part of the coast the sandstone formations are overlain by alternating beds of shale and thin sandstone, the shales being finely laminated and loosely consolidated. As already mentioned, the headland of Tinosa is formed of tabular sandstones which are full of an orbitoidal type of *Foraminifera*. There is little doubt, therefore, that the high calcium carbonate content of these sandstones is due to the presence of the *Foraminifera* in large numbers.

At Punta la Barca are exposures of sandstones and shales which are, in all probability, the same as those previously described in connection with the coast sections farther north. From Punta la Barca to Punta Tinosa the formations dip generally eastward, though small faults, chiefly of a normal type, are common in this section. It is important to notice, however, that most of the stratigraphic dislocation is confined to certain zones which are defined by faulting on a major scale. At Punta la Barca a series of step faults are found at regular intervals for a distance of 50 yards, and the downthrow is toward the south with an average throw of 6 feet in each successive step. North of

this headland a thrust zone occurs, where the multiplicity of faults can be described only as a shatter belt. In this section also the faulted rocks clearly illustrate the phenomena of drag and shear, the respective stages being followed through a well defined sandstone horizon.

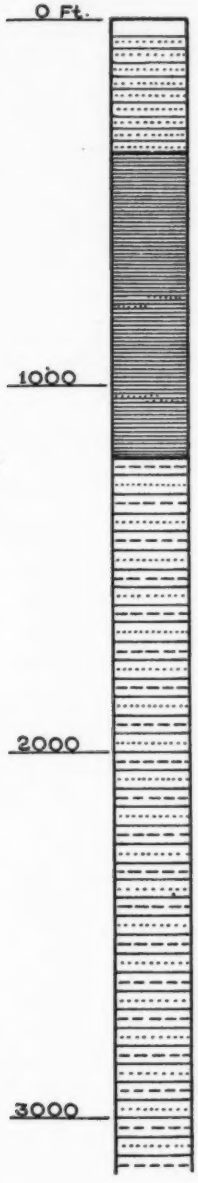
TABLE I

GEOLOGIC FORMATIONS, SOUTHWEST ECUADOR
(PRE-QUATERNARY SUCCESSION)

| | |
|---|---|
| Canoa formation | PLIOCENE |
| Bajada sandstones and grits | MIOCENE |
| Ancon Point formations | |
| 1. Ancon white sandstone | |
| 2. Variegated shales and sandstones | |
| 3. Massive sandstones (ball type) | |
| 4. Laminated shales and sandstones | OLIGOCENE (lower) |
| 5. Tabular sandstones (gastropod zone) | |
| 6. Basal breccia | |
| *Unconformity* | |
| Seca formations (Punta Blanca shales) | EOCENE (upper) |
| Socorro formations | EOCENE (upper) |
| Clay pebble bed | EOCENE (upper) |
| Middle grits (not exposed in Ancon area) Conglomerate horizons (Manabi) | EOCENE (middle) |
| Guayaquil limestone | EOCENE (lower) |
| Chert | probably upper Eocene |
| Igneous | Post-Eocene and pre-Oligocene intrusions Plutonic rocks (syenite) at Pascuales |

TABLE II

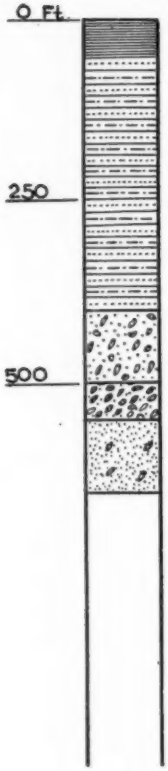
GENERAL STRATIGRAPHIC SUCCESSION, SANTA ELENA REGION




| | |
|---|---|
| PLEISTOCENE | Raised sea beaches known as tablazos. Calcareous fossiliferous horizons, with loosely consolidated sands and shales |
| L. OLIGOCENE | Fine to massive sandstones with shales, local breccia beds at base with detrital volcanic rocks. Unconformity at base |
| U. EOCENE | Known in this area as the Seca shales; homogeneous siliceous shales containing a large amount of volcanic glass. *Radiolaria* and *Foraminifera* common, also large siliceous concretions. These shales are in places interstratified with thin sandstone beds which are slightly fossiliferous |
| U. EOCENE | This series consists of interbedded sandstones and shales in the upper 1,500 feet which include the unique formation known as the Clay pebble bed, below which are massive sandstones with a few horizons of fine quartzite grit, passing locally into conglomerate. The lower sandstones are compact and siliceous, shales being rare at this depth. Though drilled deeper than 4,000 feet in the Ancon area, the base of the Eocene has not yet been reached |

TABLE III

GENERAL SECTION BETWEEN CALLO AND MACHALILLA




Seca shales, light gray to white siliceous shales, veined by quartz, locally crushed and contorted. Massive veins of brecciated chert and nodular masses occur near the contact of these shales with igneous intrusions

Socorro sandstones (Callo stage), dark brown, loosely consolidated sandstones of tabular habit, containing much volcanic breccia and interbedded with thin strata of greenish, compact shale having the texture of a slate

Coarse breccia of volcanic débris

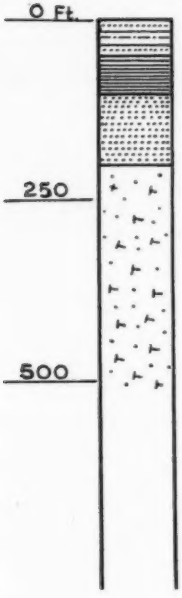
Coarse breccias as above with tuff and volcanic agglomerate at base. Large boulders of igneous rock

Coarse sandstone with volcanic material, thickness unknown

A small dike of igneous rock forms the tip of Punta Callo, also small islands of the same material. This type of igneous rock is coarsely crystalline and has intruded the sedimentary formations referred to previously

TABLE IV

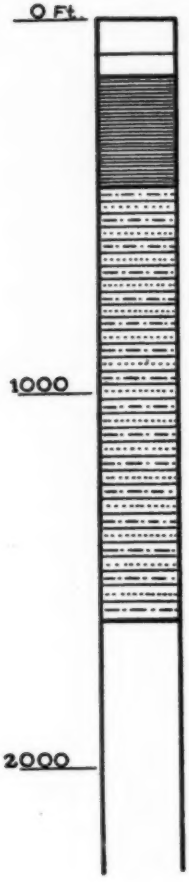
GENERAL SECTION AT PUNTA SALANGO




| | |
|---|---|
| L. OLIGOCENE? | Brown laminated sandstones, et cetera, with selenite partings very similar to the Ancon Point sandstone |
| EOCENE | Seca shales |
| EOCENE | Socorro sandstones, coarse brecciated sandstone with included volcanic débris |
| IGNEOUS | Compact, dark intrusive rock, probably a sill, thickness unknown |

TABLE V

SECTION BETWEEN PUNTA SAN LORENZO AND CALLO




| | |
|---|---|
| PLEISTOCENE | Tablazos, well exposed at Punta Canoa |
| PLIOCENE | Greenish gray fossiliferous silt (the Canoa silt), unconformable on the Tertiary formations |
| EOCENE | Punta Blanca shales (phase of the Seca shales), light gray, soft shales with large concretions, upper part fossiliferous containing large bivalves with fish scales |
| EOCENE | Socorro sandstones, coarse to brecciated sandstones with argillaceous partings. Local conglomerates at base, thickness unknown |

## DESCRIPTION OF FORMATIONS

### EOCENE

*Guayaquil limestone.*—The Guayaquil limestone was first described by T. Wolf (at one time state geologist to the Republic of Ecuador) as a Cretaceous formation, his opinion being based upon certain fossils which were sent to Geinitz, of Dresden, who identified undoubted Cretaceous forms. The following extract is taken from Wolf's book, *Geologia y geografica del Ecuador* (1892).

Fossils have been found in one locality only, that is, near Guayaquil. I have in my possession several thin layers of rock, of a calcareo-siliceous nature, which are full of impressions and fragments of shells. Similar material has been observed by me several times as it is commonly used for repairing the streets of Guayaquil. I have searched in all the quarries and excavations around the city for these fossiliferous beds but without result, and it seems to me that the quarry from which the fossils were collected is not used at the present time, or possibly the pit is now overgrown and obliterated. The commonest fossil fragments have the appearance of *Inoceramus*, this form characterizing the Cretaceous rocks all the world over. The greater proportion of these shells are so crushed and disfigured that it is almost impossible to determine their species. In several of the better preserved specimens I recognized *Inoceramus roemeri* Karst. and *I. plicatus* d'Orb. both of which are found in the Cretaceous beds of Colombia. The specimens which I have identified as above have been placed in the museum at Quito. At a later time, I took these fossils to Europe and they were examined by Dr. Geinitz, of Dresden, probably the greatest authority on the Cretaceous fossils. According to him the fossils which the rocks contain in large numbers do not include *Inoceramus latus* Sow. which are found in many European countries, and especially characterize the Upper Turonian. According to this we must assign the Guayaquil limestone to the Middle Cretaceous.

The Cretaceous formations of the coast-belt, near Guayaquil, appear to rest directly upon the crystalline schists and granites....and also according to observations made near Pascuales, syenite is covered by Cretaceous rocks.

In order to obtain an authoritative expression of opinion regarding the geological age of this limestone, the writer dispatched both specimens of the rock (collected personally at Guayaquil) and a microscopic slide of the same material, to Wayland Vaughan, the well known authority on *Foraminifera*, of the University of California. Vaughan's comments in part follow.

....the principal organism on the slide is a small lenticular species of *Discocyclina*. There are several vertical sections and there are also sections which show the equatorial chambers....the species is very close to *Discocyclina cubensis* Cushman. We have been referring the deposits in Cuba in which *D. cubensis* occurs to the upper Eocene, but I am not entirely sure that the horizon

is quite so high. However, your rock is certainly Eocene. The chances are that it belongs to the upper part of that series. If the beds from which your specimen came were ever referred to the Cretaceous, the determination of the stratigraphical horizon was erroneous.

From the foregoing it is seen that Wolf's original observations on the Guayaquil limestone were probably based upon the identification of wrongly labelled specimens.

This formation having been definitely referred to the Eocene (and probably the upper Eocene), the problem at once arises as to its correlation with the other known Tertiary horizons of this same region. Most of the Tertiary formations of the coast belt consist of sandstones and shales, with local grits and conglomerate, and, with the possible exception of the Seca shales, none has any similarity whatsoever to the Guayaquil limestone. The Seca shales and the Guayaquil limestone are lithologically similar in many ways, as both are fairly fissile and thin-bedded, and have a dominant light color. Their chemical composition, however, is quite different, the one being a typical limestone with a fairly high percentage of calcium carbonate, and the other (the Seca shales) being very siliceous. In the province of Manabi, near Monte Cristi, the white outcrops of the Seca shales are very common, a fact which no doubt led Wolf to designate them as Cretaceous rocks by reason of their general similarity in appearance to the limestone formations of Guayaquil.

Near the town of Chongon, near the foot of the westward-dipping escarpment of the Guayaquil limestone, the Miocene formations are found, and although the actual contact between the two series is obscured, it is probable that the junction between the Miocene and the limestone is in the nature of an overlap. Although the assumption that the Guayaquil limestone and the Seca shales are possibly of the same age is put forward with the greatest reserve, the difference in their respective chemical compositions may be explained by a consideration of the regional conditions under which their sedimentation took place. The deposits which later became consolidated into the limestone were probably derived from the western escarpments of the main Andean range, consisting largely of true limestone deposits which are possibly highly calcareous in composition. The Seca shales, however, are siliceous, the greater part of the silica having been derived from the admixture of volcanic glass and a few siliceous organisms. No formations, however, have yet been observed in the western part of this region (west of the Cordilleras de Chongon) which can be correlated satisfactorily with

the true Guayaquil limestone, and for this reason alone the latter deposit must be classed provisionally as lower Eocene.

At Duran, on the opposite side of the river from Guayaquil, other outcrops of this limestone are found, and a small occurrence is also found at Punta Piedra, a settlement about 25 kilometers down the river from Guayaquil. An exposure of syenitic rock occurs in association with the shales of Punta Piedra, this being similar to the syenite of Pascuales, where the igneous rock is overlain by calcareous formations of Eocene age.

*Socorro sandstones and shales (Callo district).*—This group of formations, though described collectively as sandstones and shales (from its type development in the Santa Elena peninsula) forms a distinct series which includes coarse sandstone, fine volcanic breccias or tuffs, and agglomerates consisting largely of rolled fragments of volcanic rock with the addition of similar detritus. As a general rule, the conglomerate horizons are found near the base of the series. In consideration of the different lithological types which are found in this series of sediments, it seems highly probable that during the process of sedimentation of these Eocene formations, a large amount of volcanic ejectamenta became incorporated, having been derived from the volcanic center of Cerro Bravo, in the vicinity of Jipijapa. In this district all the Tertiary deposits are characterized by the presence of ash and associated débris. This phase of the Socorro, which is well developed on the coast north of Punta Callo, is incoherent in habit, and seems to have been very loosely (and probably rapidly) accumulated. A characteristic feature of the series, also, is the presence of thin bands of shale, which normally are interstratified with the more sandy elements of the group.

In regard to the type Socorro formation which has been described previously in connection with the southerly part of the region (the Ancon district of Santa Elena),[1] the evidence brought forward for the upper Eocene age of the series is fairly conclusive. According to Olsson,[1] *Phacoides subpennsylvanicus*, certain *Nummulites*, *Operculina*, and other fossils indicate clearly that the Socorro forms part of the upper Eocene, this being part of the lower Lobitos formation (Bosworth) in Peru. Additional work by Vaughan forms evidence corroborative of the views previously expressed in connection with the geological age of this type deposit.

Specimens from the sea coast at Ancon, Santa Elena Peninsula, Ecuador, collected by H. S. Gale and F. L. Wilde, were examined by W. P. Woodring,

[1] G. Sheppard, "Geology of Ancon Point, Ecuador," *Jour. Geol.*, Vol. 36 (1928), No. 2.

who reports *Orthophragmina* sp. probably *O. peruviana* Cushman, *Orthophragmina* (stellate species) and *Lepidocyclina* sp. cf. *L. peruviana* Cushman. These species indicate the presence of deposits of upper Eocene age at this locality.[1]

.... the upper Eocene foraminiferal fauna of Ancon, Santa Elena Peninsula, Ecuador, is different from that of the Eocene Lobitos formation of the vicinity of Paita, Peru (Bosworth, 1922; Henry Woods, 1922; Cushman, 1922; Lisson, 1922). Professor Lisson has kindly sent me topotypes of his *Lepidocyclina* (*Lepidocyclina* r. *douvillei*) from Los Organos Chicos, a locality of the Lobitos formation. This species is not represented in the collection from the Santa Elena Peninsula. On the other hand I have found no *Asteriacites* in the material from the Lobitos formation examined by me. The Lobitos is correlated by Henry Woods, I believe correctly, with part of the Claiborne group of the Gulf States and it, therefore, represents a lower horizon than the upper Eocene exposures at Ancon.[2]

*Conglomerate horizons.*—The conglomerate horizons found in the Tertiary deposits are a distinctive feature in the coast sections from Punta la Barca southward to Isla de Salango, and occur in association with the upper Eocene formations. The first conglomerate of any importance is found at Punta Cangrejo, and from this headland southward to Punta Tenidero the normal Eocene sandstones in many places alternated with well defined beds of conglomerate.

The northeasterly flank of Punta Tenidero is made up of a series of these deposits and includes at least six separate horizons which range from 1 to 50 feet in thickness. The constituent boulders of these deposits include large igneous blocks (volcanic) consisting principally of lava and tuff. They differ considerably in size and shape, but are for the most part well rounded or subangular (Fig. 4). With the exception of the Basal breccia which is found at the bottom of the Oligocene at Ancon Point, few formations of a like nature have been observed in the southern part of this region. From the results of deep drilling in the Ancon area, however, it has been ascertained that well defined conglomerates or grits occur beneath the Clay pebble bed. These have been referred to in the geological column as the Middle grits. It is probable that these Middle grits are homotaxially equivalent to the conglomerate horizons already described, which are found so commonly in the province of Manabi.

The Middle grits consist chiefly of rounded black and white quartzites, with included volcanic rock and decomposed plagioclase feldspars.

[1] T. W. Vaughan, "American and European Tertiary Larger Foraminifera," *Geol. Soc. Amer. Bull.* 35 (1924), pp. 785-822.

[2] T. W. Vaughan, "Foraminifera from the Upper Eocene Deposits of the Coast of Ecuador." *Proc. Natl. Acad. Sci.*, Vol. 12 (1926).

FIG. 4.—Conglomerate, or tuff, associated with Tertiary sediments, south of Punta Callo.

They are lenticular in habit; also they differ remarkably in thickness, as shown by the respective well borings closely grouped in the area.

Thus it is indicated that the formation has been consolidated either as an estuarine deposit or as a shallow tidal beach. It may, however, represent a debouchment zone of a large river comparable with the wide estuary of the Guayas at the present time.

Fine grit beds have been observed in the Miocene and in the Quaternary; these, however, are much higher stratigraphically than the deposits previously described.

*Seca shales.*—The Seca shales form one of the most constant horizons in the region just discussed. They are almost certainly the same as the Seca shales of the Santa Elena district and the Cordilleras de Colonche, and are no doubt equivalent, in a stratigraphical sense, to the Punta Blanca shales described later. They consist of cream or white siliceous shales, thinly bedded, and of a porcelain-like texture. They are ordinarily intersected by minute veins of secondary silica, and large masses of chert are developed near their contact with igneous intrusions. Under the microscope it has been observed that the Seca shales near Callo contain large numbers of *Radiolaria* and *Foraminifera* preserved in the more siliceous zones of the deposit.

The shales are exposed in the cliff sections immediately south of Callo, appearing with slight disconformity over the sandstones and

breccias of the same sedimentary group. They are seen along the coast almost as far as Machalilla, and are present at Punta Salango, where they are in contact with part of the Lorenzo-Salango sill.

Extreme silification is marked near the contact with the igneous rocks, and the shales are sheared and contorted as a result of the intrusion. The cherts which occur near the junction with the igneous rocks are due to metamorphic action induced by them. The basic nature of these intrusions makes it very improbable that there was any addition of silica from this source, so that the formation of the cherts is probably due to the redistribution, under the influence of heat and solvent gases, of silica already present in the shales. The metamorphic action may reasonably be supposed to be confined mainly to the shatter zone caused by the intrusion, the joints or fissures so formed affording easy passage to magmatic vapors.

It is improbable that the *Radiolaria* in the rock contributed largely to the chert formation, inasmuch as they are all well preserved in the chert, continuing to the igneous contact.

In the region near Monte Cristi the Seca shales are white and flinty in texture near the igneous rocks, though along the coast in the vicinity of Jaramijo and elsewhere the shales appear to be more normal in habit, and are easily disintegrated.

*Seca shales* (*Punta Blanca stage*).—The Punta Blanca shales are exposed as a continuous section for many miles along the coast south of the settlements of San Lorenzo and Las Pinas. Lithologically, they comprise an almost pure type of soft, argillaceous shale, though a small amount of calcareous material also may be present. The shales are ordinarily unfossiliferous, but toward the top of the series the strata contain specimens of a large bivalve (*Cyprina ?*) all of which are found in a crushed condition. Fragments of fossil wood and a few fish scales have been noticed also in the same deposit.

The formation of these shales has been governed by uniform conditions, having taken place in a large enclosed basin, undisturbed either by wave or by current action. The rock itself is fairly coherent and homogeneous, and well defined horizons of hard, ovoid nodules are common, which in many places form prominent ridges under the influence of marine erosion. The concretionary masses are veined by calcite, in addition to a small amount of ferrous separation along the joints or minute fissures in the rock. The Punta Blanca shales disintegrate rapidly and flake off the exposed surfaces in small fragments, thus forming almost vertical light gray or white cliffs. These shales have

many features in common with the type Seca shales of the Ancon area of Santa Elena, which also are characterized by the presence of exceptionally large concretionary masses.

### MIOCENE[1]

The Miocene deposits found in the region consist mainly of loosely consolidated sandstones which are locally very fossiliferous, in which respect they are in marked contrast to the older deposits of the Tertiary. Here and there are found also fine grits grading into conglomerate, which are similar, in a lithological sense, to the sediments which occur in both the Chanduy and the Saya hills. The Miocene sandstones are exposed east of the Cordilleras de Colonche, where they overlap a dark hypabyssal rock near the settlement of Quiquisale. From this point they extend eastward almost as far as Rio Daule, where they are overlain by alluvium and river silts. Good sections of the Miocene are found also along the river east of Estacada, these sections including fossiliferous limestones interstratified with calcareous shales. The Miocene beds have a considerable areal extent, being continuous throughout the region east of the Cordilleras de Colonche and northward to the vicinity of Jipijapa (Plate 1). Here the Seca shales appear, possibly forming a fault-contact with the Miocene. Near Jipijapa the Miocene and Eocene are closely associated, and it is possible that a defined overlap occurs, as no representatives of the Oligocene, such as are found at Ancon Point, have yet been observed.[2]

### PLIOCENE

*Canoa formation.*—This stage of sedimentation forms a unique deposit in the stratigraphy of the region, and has been observed in one locality only, namely, along the coast from Punta Blanca southward to Punta Canoa. The formation occurs beneath the true tablazo of the Quaternary, and rests unconformably upon the denuded and inclined strata which have been described previously as the Punta Blanca shales (Fig. 5). The formation itself is a compact and tenacious sandy silt of a bluish gray color, and is crowded with many species of fossils, most of which seem to be of Pliocene age. There is little doubt that this deposit represents the sedimentation of a lagoon or inland sea which covered an extensive area, and was formed before the formation of the

[1]G. Sheppard, "Notes on the Miocene of Ecuador," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1928), pp. 671-73.

[2]G. Sheppard, "The Geology of Ancon Point, Ecuador," *Jour. Geol.*, Vol. 36 (1928), No. 2.

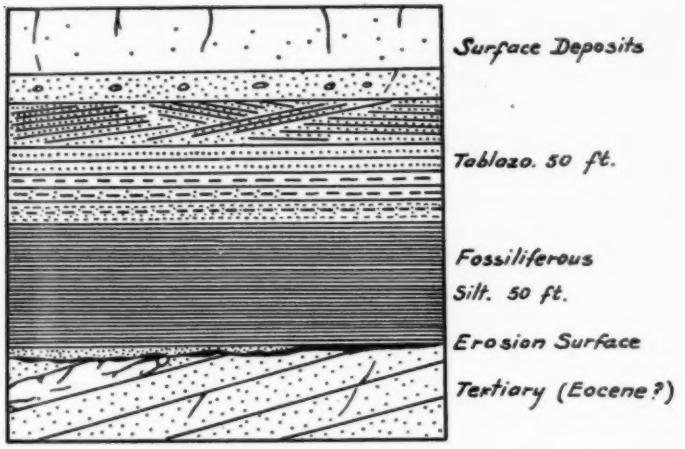



FIG. 5.—Section showing unconformity between the Canoa silt (Pliocene) and the Punta Blanca shales (Eocene).

tablazos. So far as is known at present, this is the only recorded example of a deposit intermediate between the known Tertiary and the tablazo in Ecuador. A similar phase, however, has been noticed in northwest Peru, this having been described as the Sechura formation of the Pliocene.[1]

QUATERNARY

Little can be added to what has already been written on the Quaternary deposits, or tablazos, which are found bordering the shores of this section of the coast. Their distribution, however, is not general, though at least three terraces are found in the vicinity of Manta, Monte Cristi, and Callo. At Punta Canoa about 10 miles north of Callo, at Punta Tenidero, and near Punta San Mateo, the tablazos form well defined terraces, and differ but slightly from those of the Santa Elena region farther south.

In previous literature reference has been made to the Quaternary terraces, or raised sea-beaches, of Peru,[2] and attention has been called to the large quantity of fossil driftwood which is found in these deposits. A characteristic feature of this wood is the fact that it is per-

[1] A. Iddings and A. A. Olsson, "Geology of Northwest Peru," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1928), pp. 1-39.

[2] T. O. Bosworth, *The Geology and Paleontology of North West Peru* (1922).

forated by boring molluscs, this phenomenon suggesting that the wood itself has been floating in the ocean, or in the estuarine currents of that period, for some time, until it became water-logged and later embedded in the sediments of the coastal shelf. The tablazos of Peru contain pebble beds and conglomerate horizons of differing magnitude which have been derived in part from the local Amotape Mountains and, according to Bosworth, in part from the Andes farther north. Breccia fans are also a feature of the Peruvian Quaternary deposits. Though it is believed that the three Quaternary terraces previously described in connection with the geology of northwest Peru are represented in Ecuador at approximately the same levels, certain lithological differences are found which may indicate special phases in the deposition, or may give some idea of the direction of the principal currents which contributed to the waters of the ocean of that period. Fossil driftwood is practically unknown in the Quaternary of Ecuador, and the writer can recall no occurrence of this nature in the tablazo formations. No doubt such material does occur in these deposits, but it must be exceedingly rare. Breccia fans and pebble beds in the Quaternary are only slightly represented in Ecuador, and never attain the size of those described from the similar deposits in Peru.

The tablazo levels occur at elevations of 10, 250, and 350 feet above present sea-level. These deposits form definite peneplains in the topography, the flat-topped hills being characteristic of the coast belt. In places, as at La Puntilla and near the hills of Colonche, the three levels can be seen in the same section, and it is believed that these erosion remnants so formed have been preserved, because the upper tablazo (the oldest) consists of hard, calcareous conglomerate, or of limestone. The lithological constitution of the tablazos differs considerably, and shell limestones or conglomerates are replaced laterally by loose, current-bedded sands and light calcareous shales within very short distances. Thus it can be readily understood that the erosion remnants consist largely of the harder or more resistant lithological forms, the softer deposits having been denuded by the normal forces of climatic action which are peculiar to this part of the world. Toward the north the tablazo terraces recognized on Isla de la Plata occur approximately at 100, 500, and 740 feet above sea-level, and on the mainland in the vicinity of San Lorenzo and Manta similar deposits have been observed. With the exception of the Manta district on the north and the Santa Elena region on the south, the Quaternary seems to be developed only slightly along the intervening littoral, and it is certain that the Quaternary

sea did not extend very far inland from the present coast line. Nevertheless, the presence of tablazo deposits on the island of La Plata, situated about 15 miles from the mainland, signifies a considerable westward extension of the coast line during Quaternary time.

The crustal oscillations of the coast belt have been described fully by Bosworth in connection with northwest Peru, and it is probable that tectonic movements of the same order were developed along the shores of southern Ecuador. In Ecuador, however, the following points must be considered. The vertical interval between the oldest and the newest tablazo is, in places, as much as 700 feet; hence, it may be assumed that since the beginning of the Quaternary the first tablazo was accumulated upon the denuded beds of Tertiary age, and the oldest uplifted to a height of at least 700 feet before the close of the same epoch. This coastal uplift was not continuous but, as is exemplified by the tablazo remnants preserved at present, it was divided into at least three stages, each stage or temporary halting of the uplift being marked by the sedimentation of a tablazo unit. After the emergence of the older tablazo from the shallow Quaternary sea, a further incursion took place which may indicate a temporary subsidence of the terrane. During this interval the second tablazo was formed. The general uplift movement then continued, causing the emergence of the second tablazo, and later the formation of the third terrace. These static intervals were naturally followed by further sedimentation, and there is good reason to believe that the coastal uplift is continuing at present.

The relative thicknesses of the respective tablazos indicate time intervals during the Quaternary, and in order to account for the accumulation of material in an individual tablazo, possibly 50 feet in thickness, it must be considered that the littoral zone of that time subsided approximately 50 feet. Thus we may infer that though the terraces of Quaternary age, which are now found as a margin of the Tertiary formations of the coast belt, indicate successive uplifts of the terrane during the Quaternary, it must be assumed in addition that these temporary cessations in the tectonic uplift alternated with intervals of relative subsidence.

The earth movements here briefly outlined had undoubtedly an important influence upon the attitude and the structure of the underlying Tertiary formations. At the close of the Tertiary period the coast line of Ecuador extended much farther westward than at present, this being proved by the evidence of soundings along the coast, and by the presence of Tertiary igneous masses on Isla de la Plata. It has been

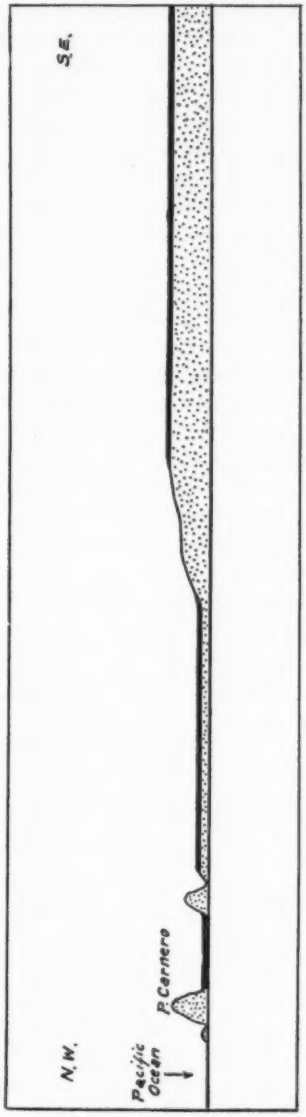



FIG. 6.—Diagram illustrating tablazo levels near Punta Carnero, Ecuador. Length of section, 2,000 yards. Highest level, 200 feet.

proved also that the Tertiary sediments were subjected to great tectonic movements, with a consequent dislocation and crushing of the strata and a development of igneous intrusions. These events took place in post-Tertiary and pre-Quaternary times, an interval which must have been considerable. Then followed a phase of intense subaerial denudation which antedated the formation of the tablazos. In order to explain, however, the great incursion of the Quaternary ocean which took place in this region, it must be assumed that a subsidence of the Tertiary land surface followed which antedated the deposition of the oldest tablazo. This foundering of the Tertiary is an episode of considerable geological importance, as it may be associated with the tectonic uplift of the Andes, the intrusion of igneous dikes, and the manifestation of volcanic activity, and it may have been a contributory cause of the disturbed nature of the Tertiary formations, which is well exemplified at present. The consequent uplift and minor oscillations of this same land mass which followed in Quaternary time, must have had a further influence upon the already disturbed Tertiary formations. It is indeed possible that the block-faulting of the Tertiary, which forms so characteristic a feature in the coastal zones of both northwest Peru and southern Ecuador, was induced primarily by a tectonic warping of the regions here outlined.

## STRUCTURAL GEOLOGY

This region may be divided into three structural units, the block-faulted zone of the coast belt, the uplift known as the Cordilleras de Colonche, and the Miocene country between this uplift and Rio Daule. Although it is believed that the Cordilleras de Colonche form a tectonic phase which has an orogenic connection with the main Andes, it must be noticed that the Andes are situated at least 100 miles farther east, and have a much greater elevation than the ranges nearer the coast.

In Ecuador, the Andes proper follow a line slightly east of north, forming part of the same mountain system which is found in both Peru and Colombia. The range known as the Cordilleras de Chongon (with its continuation, the Cordilleras de Colonche) forms a subsidiary spur of the Andes, but trends almost at right angles, having a general direction toward the northwest. North of Colonche, however, the faulted nature of the Tertiary formations is so confusing that, with a few minor exceptions, it is impossible to recognize even a general orientation of the more elevated ranges. Between the Cordilleras de Chongon and the Andes proper, extensively denuded outcrops of a syenitic type of rock,

for example, at Pascuales and Punta Piedra, are found, and as these seemingly bear no petrographic relationship to the more recent types of hypabyssal rocks which have been referred to in a previous section of this paper, it must be assumed that they represent a denuded horst, which is probably pre-Andean in age. The Cordilleras de Chongon do not include sedimentary formations older than the Tertiary, though these rocks have been described in several publications as Cretaceous.[1]

Wayland Vaughan has expressed his opinion, based upon the evidence of the *Foraminifera*,[2] that the Guayaquil limestone is Eocene in age. Cretaceous formations, however, with plutonic igneous masses, are known to occur east of the Andes,[3] and similar shales have been recorded also from the Loja district southwest of the Republic. There is a possibility, therefore, that the structural conditions found in the region between the Cordilleras de Chongon and the Andes may approximate a depressed orogenic scarp or block which, after a long period of denudation, formed a basin for the later deposition of the Miocene. The Miocene overlaps the Guayaquil limestone in the vicinity of Chongon. The general block-faulted structure of the older Tertiaries toward the west, that is, along the actual coast belt, is rendered more obscure by the presence of the intruded hypabyssal rocks and contemporaneous lava flows, the latter having been referred to in the earlier part of this paper. It is of interest to notice, however, that in the same Tertiary formations of Peru, no similar igneous rocks, with cherts, have been recorded, but there is an undoubted similarity in the nature of the block-faulting and in the subsidiary folding which has been described as occurring in this country south of the region here discussed.

Apart from the denuded fault scarps in the Tertiary in the south part of the province of Guayas, known respectively as the Cerros de Chanduy, the Cerros de la Estancia, the Cerros de Saya, et cetera, an exceptional form of conglomerate is exposed in the small hills known as the Cerritos del Morro (east of Playas). This formation may, in itself, represent an erosion remnant of a much older land surface, and seems to have very little connection stratigraphically with the other sediments of this region. In Ecuador the Miocene deposits are rarely so disturbed as the older Tertiary, and whereas the latter formations are locally block-

[1] T. Wolf, *Geografica y geologia del Ecuador* (Leipzic, 1892).

[2] G. Sheppard, "The Age of the Guayaquil Limestone," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13 (1929), pp. 383-84.

[3] T. Wasson and Joseph H. Sinclair, "Geological Explorations East of the Andes in Ecuador," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 1253-81.

faulted and in places include definite shatter belts, the Miocene beds present gentle folds of low dip with very little structural dislocation. It must be borne in mind that igneous rocks are nowhere found associated with either the Miocene or the later Quaternary, a fact which has been commented upon previously.

The structural geology observed during the course of a traverse made across the southern part of the Cordilleras de Colonche, that is, from Guangala east to Estacada, is typical of the major tectonic units. Igneous rocks of a hypabyssal form occur east of the sediments in this range, and include olivine dolerites of a foliated nature. There is reason to believe that the southwestward-dipping Tertiary beds are also intruded by dike rocks, and the large chert hills, known collectively as the Cerro de Isera, certainly indicate the presence of igneous intrusions. The Tertiary formations which compose the major section of the Cordilleras de Colonche consist of steeply inclined sandstones and shales which have a more or less uniform dip toward the south or southwest. East of the highest part of the range is an extensive outcrop of dolerite, the folia of which are inclined in the same direction as the sedimentary rocks they intrude. The evidence, however, is not sufficient to determine whether the tilting of the sediments has been caused by the intrusion, or whether the dike had been intruded later into the formations which were previously in an inclined state. East of this igneous outcrop, at the settlement of Quiquisale, the Miocene deposits rest almost horizontally upon the darker hypabyssal rocks. At the contact of these formations the fossiliferous Miocene (the Bajada formation) appears to be slightly metamorphosed, although the sedimentary formations are quite undisturbed at the contact. This suggests that the contact between the Miocene and the igneous is in the nature of an overlap, rather than that the Miocene had been intruded by the hypabyssal rock.

Eastward in the direction of Estacada, and possibly as far as Rio Daule, the Miocene deposits are gently folded into a series of parallel anticlinal folds having an axial trend toward the northwest. The Miocene formations which, as already mentioned, have an areal distribution north of the Cordilleras de Colonche almost as far as Jipijapa, appear as westward-facing escarpments of low dip toward the east, the range known as the Cerros de Guanaveno being an example. In a general sense it may be stated that although the inland exposures of Miocene rocks dip eastward at a low angle, the earlier Tertiary coastal formations, though block-faulted and disturbed by igneous intrusions, indicate a structural declination toward the west. In this connection

it may be mentioned that in the region farther south a large anticlinal fold occurs in the Miocene beds, near San Jose de Amen, the axis of which has a northwestward trend, possibly continuing as far as the coast in the vicinity of Colonche. The problem of the origin and the distribution of the cherts has been discussed fully elsewhere,[1] yet it is necessary to point out that in addition to the fact that the cherts are highly contorted as a direct result of the different igneous episodes, they nevertheless occur in zones which form undoubted areas of extreme structural compression, or tectonic dislocation. It is difficult to express any opinion regarding the relative age of the igneous intrusions, and although in some places the structural features displayed by the attitude of the sedimentary formations appear to be a direct result of igneous intrusion, there is also the possibility that the hypabyssal manifestations followed lines of structural weakness. It is well known that in certain parts of the world a plane of dislocation in the superficial formations has resulted in hypabyssal activity, the igneous magma finding an avenue of release through the medium of the disturbed zone in the sediments. Having regard to the many places in southern Ecuador where hypabyssal rocks have intruded the Tertiary formations, it may be tentatively suggested that the dikes and sills are of later date than the tectonic compression of the sedimentary formations. In other words, the igneous rocks have been forced above the older Tertiary strata through the media of zones of structural weakness which were caused primarily by crustal dislocation.

The researches of Bosworth and other observers, in the geology of northwest Peru, have disclosed the fact that the Amotape Mountains, which form an outstanding subsidiary range west of the Andes, include much older formations than have yet been discovered in the more westerly outliers of the Andes in Ecuador.

Slates of Carboniferous age, with associated schists and quartzites, are found in the Amotapes, these having been intruded by a large granite mass which has caused extreme metamorphism at its contact with the sedimentaries. In the region under present discussion, the only plutonic occurrence is a denuded outcrop of syenite near Pascuales, and no sedimentary rocks older than the Cretaceous have been recorded. According to Wasson and Sinclair,[2]

> the most prominent characteristic of the Andean uplift in Ecuador is its narrow base of precipitous sides, the mass being less than 90 miles wide at the base,

[1] G. Sheppard, "Chert Deposits in Ecuador, South America," *Geol. Mag.*, Vol. 65 (1928), No. 770.

[2] T. Wasson and Joseph H. Sinclair, "Geological Explorations East of the Andes in Ecuador," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 1253-81.

and 40 miles wide at the top. The plateau summit is about 9,000 feet in elevation, and from this general level rise volcanic cones to elevations of 18,000 to 20,000 feet.....The sides of the volcanic peaks are covered with extrusive volcanic débris, much of the material on the plateau being in the form of pumice. The general aspect of the slopes of these volcanic peaks gives the impression of very recent volcanic activity.

## HISTORICAL GEOLOGY

The principal events in the historical geology of the region may be briefly outlined. As will be seen from the general map (Plate 1) the coast belt proper consists entirely of Eocene and possibly Oligocene rocks, the latter being typically developed at Ancon Point, at Punta Montanita, on the southern flank of Punta Salango, and at Punta Mambra. The Oligocene beds are considered to form the greater part of the western area of the Santa Elena peninsula, with the exception of the cherts which are assumed to be associated with the Seca shales, and to be of upper Eocene age. East of this Eocene region there is an extensive development of Miocene which continues farther east than is indicated on the map, and probably underlies the whole of the Daule basin, and may extend as far as the frontier zone of the main Andes.

It is not believed that the Miocene beds in the past covered the formations much farther west, that is, over the Eocene and Oligocene formations, than is indicated on the map, as no erosion remnants of the Miocene have been observed in this region. Farther south, however, in the vicinity of Zapotal, there is evidence of a Miocene shore line near the slopes of the Cerro de Zapotal.

The stratigraphical relation between the Miocene and the older Tertiary is not quite clear, as a distinct overlap of the Miocene occurs east of the Cordilleras de Colonche, though it is believed that these beds normally succeed the Oligocene sandstones in the low hills southeast of Colonche (north of the Cerros de Saya). Too much importance, however, must not be attached to the relatively undisturbed condition of the Miocene beds as compared with the general geological structure of the older Tertiary formations. The block-faulted and, in places, overthrust condition of the older Tertiary strata seems to be confined to the western part of the region, and it is certain that though the general tectonic forces which influenced the nature of the structure in this part left their impress in the disturbed condition of the older Tertiary, it is quite reasonable to assume that the later Miocene also became involved in the movement, though to a lesser degree. Nevertheless, the presence of igneous intrusions in the Eocene beds alone suggests crustal movement

of greater intensity than that which followed during the later Tertiary and Quaternary stages.

The middle Eocene beds are not exposed in any part of the region under discussion, but the evidence of certain drill cores and well samples which have been obtained from depths between 2,000 and 4,000 feet in the Ancon area, indicates clearly that they consist principally of grit or sandstone formations (the Middle grits). These vary in texture, and range from closely compacted, angular sandstones, to grits and conglomerates. It has been noticed that the lateral variation in these lower Tertiary deposits is great; for example, a 200-foot bed of quartzite grit thins to a stratum a few inches in thickness in a distance of 200 yards. This indicates that the beds have a lenticular habit, a condition which was doubtless caused by the estuarine nature of the sedimentation. The relative absence of shales in these lower horizons also suggests that the accumulation of sediment was fairly rapid, and was possibly along a coastal shelf, or, more probably, in a wide, yet shallow estuary. The succeeding Socorro beds of Eocene age are also shallow-water deposits, and include sandstones with intercalated shales. In these formations is found the exceptional depositional phase known as the Clay pebble beds, which are of considerable controversial interest. Apart from the lithological importance which is exemplified by these Clay pebble deposits,[1] they also signify an erosion surface with an unconformity in the middle Eocene beds. It has been impossible, however, to identify this break in the sedimentation, as, apart from the fault contacts, none of the inland exposures shows the horizon. As described more fully in a previous section of this paper, the Socorro beds vary both locally and regionally, especially in the district farther north, where there is a large admixture of volcanic detritus. The succeeding Seca shales, however, are fairly constant as a lithological unit, a feature which implies a certain uniformity in the regional sedimentation, the governing conditions being totally different from those of the underlying Socorro formations. The relative absence of sandstone horizons in the Seca shales indicates possibly a deeper basin of deposition which, for the greater part of the time, was free from the disturbing influence of currents, or the periodic debouchments of rivers. Although the evidence in favor of a true unconformity between the Seca shales and the

[1] C. B. Brown and R. A. Baldry, "On the Clay Pebble Bed of Ancon, Ecuador," *Quart. Jour. Geol. Soc.* (1925), p. 81.

George Sheppard, "Further Observations on the Clay Pebble Bed of Ancon, Ecuador," *Geol. Mag.*, Vol. 64 (1927).

Socorro beds is slender, a break is apparent in the continuity of the formations immediately south of Callo.

At Ancon Point, also, where the Seca shales thin appreciably, the lower beds rest unconformably upon the Socorro formations. A typical section in the sediments which are considered to be of Oligocene age has been described,[1] and it is of interest to notice that an unconformity occurs at the base of this series, this being represented by a basal breccia and an erosion surface. In the peninsular region of Santa Elena there is a wide distribution of the Oligocene, outcrops of which are also found in an extremely contorted condition as far north as Punta Nancy. The most interesting feature of this series is a white deposit, known as the Ancon white sandstone, the outcrops of which illustrate the nature of the faulting in a graphic manner.

The distribution of the Quaternary tablazos is not general in this region, having been observed in two localities only: (1) the Callo-Monte Cristi-Manta region, and (2) the Santa Elena region, from Ayangue south and east to Playas. They also occur on the Isla de Puna.

During the Quaternary period, therefore, the invasion of the ocean was probably not universal, and it is quite possible that certain tracts of the Tertiary, for example, the territory between the localities previously quoted, formed dry land during the deposition of the tablazos.

### SEDIMENTATION AND PETROLOGY OF TERTIARY ROCKS

From the preceding pages it is seen that the lithology of the Tertiary sediments which are found in this part of Ecuador is of a diverse character, the deposits ranging from fine silt to coarse conglomerate. It only remains to comment, therefore, upon their mode of deposition, the nature of the region in which the sedimentation took place, the geographical and other factors which brought about certain variations, and the nature of the continental land mass from which the sediments had their origin.

With a few minor exceptions, the western frontier range of the Andes forms a striking escarpment or ridge of Cretaceous and possibly older rocks, with associated igneous masses, which extends throughout the length of the country. It is true that in many places the nature of this great orogenic feature is obscured by more recent lava flows, et cetera, yet the topographical contrast between this high range and the lower Tertiary region on the west is very striking. It has been ascertained

[1] George Sheppard, "The Geology of Ancon Point, Ecuador," *Jour. Geol.*, Vol. 36 (1928), No. 2.

that the principal formations constituting the western slopes of the Ecuadorian Andes include Cretaceous limestones and igneous intrusions. Guayas River, with its tributaries, drains an enormous region west of the Andes proper, and, although this river is of a comparatively recent geological age, it undoubtedly follows a natural depression in the Tertiary strata which was formed as a consequence of the tectonic deformation of the coast belt. It may be assumed, therefore, that the Andes formed the coast line of the Tertiary ocean; most of the sediments now known to be of Tertiary age were derived, primarily, from this continental mass; and, finally, they were deposited in an extensive, though shallow, coastal shelf which extended westward for many miles beyond the coast line of the present day. This coastal shelf, however, was in a state of tectonic instability during Tertiary time, a condition which was intensified after the close of the Tertiary, and before the deposition of the Quaternary tablazos. In addition to the normal littoral deposits which consist principally of sandstones and shales with a few boulders, there is plentiful evidence that estuarine conditions, with local developments of river detritus, prevailed during this period of sedimentation. As commented upon in a previous section of this paper, conglomerate horizons are a feature of the Tertiary rocks on the north in the province of Manabi. From their local distribution, and the rounded rather than flattened appearance of the constituent pebbles, it must be assumed that these deposits were formed as river beaches or estuarine bars, and were not accumulated upon a tidal shore. On the contrary, the conglomerate which is found at Punta Ancon and Punta Mambra represents a true erosion surface, or unconformity, between two phases of the Tertiary formation. The estuarine nature of certain Tertiary sandstones is well exemplified by local phases of the Socorro beds, and in the later Tertiary in other localities.

Deep-well drilling, also, in the vicinity of Ancon has brought to light samples from grit horizons which are lenticular in habit, and may represent river bars or similar accumulations which became incorporated in the normal Tertiary sediments.

The presence of peculiar rafts of fossil driftwood and similar vegetation, among which numbers of *Aturia* have been found (specimens of which are now in the collections of the British Museum of Natural History, having been identified by Spath) is of considerable interest, as they are associated with the upper Eocene beds of this vicinity (Ancon). These lignitiferous deposits also yield specimens of fossil wood, with seeds and fruits, the common genus *Anacardium* corresponding closely

with similar fruits which have been collected from the Tertiary deposits of Peru.[1]

The mode of occurrence of these isolated lenses of fossil vegetation may be compared with phenomena which are now found in connection with the larger river estuaries of the west coast of South America, for example, Guayas River. This river is tidal almost as far as Daule, about 30 miles north of Guayaquil. From this place southward "floating islands," many of large size, consist entirely of driftwood and entangled vegetation to which certain molluscan forms of estuarine life are attached. These large rafts are drifted up and down the wide estuary in accordance with the movement of the tides until they either disintegrate completely, or become stranded upon a mud or sand bank, and are embedded in the river sediments.

The current-bedded habit of other Tertiary sandstones in which fragmentary fossils and local lenses of grit are found suggests the influence of rapid current action due, in all probability, to seasons of flood causing a temporary rejuvenation of the rivers. In this connection the deposits known as the Clay pebble beds may be borne in mind, these having been described in detail elsewhere.

Deposits of shale intercalated with the sandstone horizons do not necessarily imply deeper-water conditions, and in the Tertiary region these shales indicate a true estuarine habit where mud banks are formed in association with the sandy beds of the same depositional basin. A change in the direction of the river, a not uncommon occurrence, caused possibly by an abnormal season of heavy rains, would be sufficient to account for the presence of shales among the normal sandstones. The conditions, however, which governed the sedimentation of the Seca shales, an upper Eocene deposit of wide areal distribution, were totally different from those which were in operation during the sedimentation of the older Tertiary. The Seca shales are remarkably uniform, and, apart from the fact that they contain a considerable amount of volcanic ash, with local shales containing a profusion of *Foraminifera* and *Radiolaria*, there is reason to believe that these rocks, as a whole, were deposited in a large inland basin which was connected with the ocean of that period. The presence of volcanic detritus in most of the Tertiary rocks of this region indicates either contemporaneous volcanic activity, or intense denudation of a volcanic terrane. That lagoon phases were of frequent occurrence along the Tertiary coastal shelf is demonstrated by certain curious markings which are found in some of the ripple-

[1]E. W. Berry, *Jour. Paleont.*, Vol. 3 (1929), No. 3.

FIG. 7.—Exceptional markings on sandstone blocks, Quebrada Seca, near Ancon, Ecuador.

marked sandstones of the Santa Elena area (Fig. 7). By a comparison with phenomena of recent times, similar markings have been observed in a lagoon near Punta Centinella (Fig. 8), where the evaporation of the lagoon waters has left a thick layer, or scum (possibly of algal or diatomaceous growth), which rapidly assumed the irregular form illustrated in the photograph. By comparing these markings with the

FIG. 8 —Recent markings on surface of lagoon deposit, Punta Centinella, Ecuador.

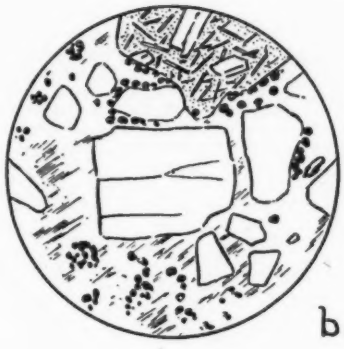
sandstone markings shown in Figure 7, it is seen that there is a certain resemblance, and that, in all probability, the markings were formed under the same sedimentary conditions.

### PETROLOGY OF TERTIARY SANDSTONES

The sandstones in this region are generally of the same petrological order; they vary in texture from fine to coarse grain, a few passing into grits, and consist principally of rounded to subangular quartz grains with the following subsidiary minerals: altered lime feldspar, magnetite, pyroxene, chlorite, primary and secondary calcite. Where the sandstone has suffered later deformation, the quartz grains have a tendency to interlock, and secondary mica and chlorite films are found filling the interstices.

Most of these sandstones are slightly calcareous and the matrix consists of interstitial calcite, which mineral has been derived either from the decomposition of the lime feldspars, or from the inclusion of foraminifers, shell fragments, or calcareous detritus of a similar nature. As shown in the sections (Figs. 9-21), volcanic lava may be present, in addition to quartzite.

Upon fresh fracture the type sandstones are light gray, and they are ordinarily soft and easily fractured. Weathered surfaces and scree material, however, are invariably of a brown or buff color, with a secondary development of selenite along the joint planes. In the Ancon Point area, and in other localities inland, the gray sandstones are fairly coarse and exhibit fissility along their bedding planes. These sandstones contain fossil wood and small ferrous concretions with nodular masses of siderite, the latter having a characteristic fibrous or pseudo-cone-in-cone structure. These sandstones are heavily veined by white quartz, the edges of the vein being colored by red oxide of iron.



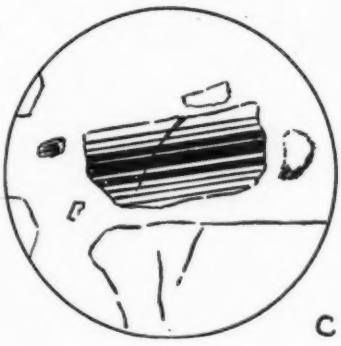




FIG. 9.—*a* (× 20), section of type rock; *b* (× 100), section showing separation of siderite; *c* (× 100), lime feldspar (under crossed nicols).

Specimen No. 1; locality, Cerro Alto, near Santa Elena, Ecuador; calcareous sandstone (Oligocene).

Fine to medium sandstone, having a slight reaction to acid. In addition to subangular grains of quartz, larger fragments of granular quartzite are present in sufficient quantity to characterize the rock. A few fragments of fresh volcanic lava, showing both small phenocrysts and a mesh of lath-shaped crystals, are also present, embedded in a glassy base. As these feldspars have an extinction angle of 45-47, they belong to a lime series, probably anorthite. Specks of magnetite occur, probably derived from the volcanic element in the rock; siderite, in minute globules, is segregated in marginal fashion around the quartz grains of the groundmass. Decomposed augite is also present, with brown biotite in small flakes. Epidote and fine volcanic ash have been identified. A few of the quartz grains are shattered and exhibit strain shadows under crossed nicols. The calcareous nature of the matrix may be due in part to the decomposition of the lime feldspars in this sandstone.

FIG. 10.—(× 100.) Section showing crystallization of calcite.

Specimen No. 2; locality, Ancon, Santa Elena, Ecuador; calcareous sandstone (Eocene).

In the hand specimen this is a gray compact rock, having the texture of a consolidated silt, but not fissile. The matrix is very calcareous and reacts strongly under acid. Under the microscope the matrix can be resolved into two phases. 1. A calcareous shale phase shows incipient crystallization of the calcite, and has the appearance of a rudimentary cone-in-cone structure. These fibrous aggregations of fine calcite exhibit a black cross between crossed nicols. This phase of the rock originated probably as a fine silt, or mud, which later became calcified, the fibrous, spherulitic crystallization of the calcite being secondary. 2. A fine-grained sandstone phase consists of angular quartz, with inclusions, altered pyroxene, and biotite, the last being altered with a separation of magnetite along the cleavage planes. A few quartz grains are fringed by calcite fibers at right angles to the edge of the quartz fragment.

FIG. 11.—(× 100.) Section of type rock showing habit of greenish mica, or chlorite, in relation to quartz crystals.

Specimen No. 3; locality, Ancon, Santa Elena, Ecuador; calcareous sandstone (Eocene).

This type is a fine-grained sandstone, having a calcareous matrix. Under the microscope most of the constituents include angular quartz, with a few rounded grains also present. The calcareous matrix is amorphous, and the quartz particles are embedded in a laminated fashion, this feature being the result of the sedimentation. In addition to the quartz the following minerals have been identified: biotite, secondary muscovite, and a greenish decomposed mica, the last probably of a secondary origin; a few fragments of lime-feldspar, with particles of granular pyroxene; and a little magnetite, probably the result of the decomposition of the ferro-magnesian minerals.

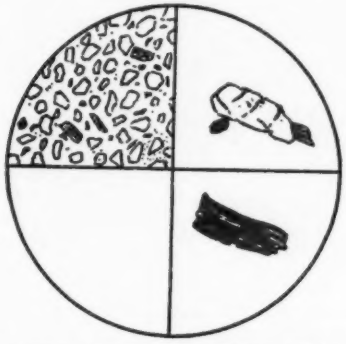


FIG. 12.—Top left sector (× 20), type sandstone; top right sector (× 100), decomposed enstatite with separation of fibrous chlorite; bottom right sector (× 100), greenish mica (altered).

Specimen No. 4; locality, near San Vicente, Santa Elena, Ecuador; siliceous sandstone (Oligocene).

This type has a vitreous aspect in the hand specimen, the individual grains being too small to be recognized without the use of a lens. The rock is of fine texture and is hard and tenacious, the groundmass being non-calcareous. Under the microscope the rock is seen to consist largely of angular quartz grains which are embedded in a siliceous matrix. Fragments of a lime-feldspar (extinction 45-47) are common, in addition to altered ferro-magnesian minerals in small quantity. Other minerals recognized include pyroxene (enstatite ?) magnetite, altered biotite, white mica, altered olivine, and isotropic volcanic glass. Rock of this type passes locally into hard, siliceous shale, the constituents of which are too fine to be resolved under the microscope.

FIG. 13.—(× 20.) Section of type rock. Large fragment of quartzite, top left sector.

Specimen No. 6; locality, Ancon, Santa Elena, Ecuador.

Specimen drilled from 3,500 feet below the surface; coarse grit (Eocene, the Middle grits). This rock consists principally of rounded and subangular fragments, the larger of which are quartzite (carbonaceous). Quartz grains also are present with fine inclusions, and included calcite. A decomposed lime feldspar also occurs in minor proportion. The groundmass is typically non-calcareous.

FIG. 14.—(× 20.) Section of type rock.

Specimen No. 7; locality, Ancon Point, Ecuador; coarse sandstone (Oligocene).

This rock has the appearance of a heterogeneous and rapidly formed sandstone composed of irregular fragments and rounded grains. Angular quartz is rare, though a few fragments of a lime feldspar (anorthite-labradorite) are present. The larger grains which make up the greater part of the groundmass consist of volcanic rock, the groundmass of which is decomposed. Minute crystals of plagioclase feldspars also occur with a separation of iron compounds such as limonite and magnetite. Small crystals of greenish augite are present. Relatively large fragments of irregularly shaped volcanic glass exhibit flow bubbles which are distorted. These are probably ejected volcanic fragments. The feldspars are ordinarily fractured and there is a considerable separation of crystalline calcite which occupies the cavities of this loosely consolidated rock. The augites in the volcanic constituents exhibit dark resorption borders.

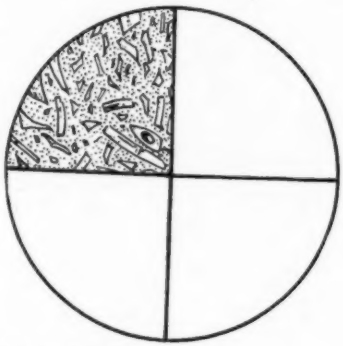


FIG. 15.—(× 100.) Section of type rock.

Specimen No. 9; locality, near San Vicente, Santa Elena, Ecuador; phase of Ancon white sandstone (Oligocene).

This is a very fine-grained clastic rock in the nature of a consolidated volcanic ash. It is non-calcareous, the groundmass consisting of gray, indefinable, siliceous powder. The glassy fragments are of a splinter form, and a few small bubbles can be seen included in the grains. Most of the individual fragments are isotropic.

FIG. 16.—(× 20.) Section of type rock.

Specimen No. 10; locality, 2 miles south of La Libertad, Santa Elena, Ecuador; calcareous sandstone (Oligocene).

This sandstone is a greenish gray, medium- to coarse-grained rock, with a calcareous matrix. The calcareous element is interstitial in habit and shows no evidence of secondary crystallization. As this Tertiary sandstone occurs immediately below the calcareous tablazo of Quaternary age, it is quite possible that the calcium carbonate may have been infiltrated from above, and later occupied the interstices between the grains of the rock. Under the microscope the sandstone is seen to consist of angular quartz grains, containing many minute inclusions. Some of the quartz grains exhibit strain shadows between crossed nicols. A few decomposed lime feldspars also are present, and fine crystalline rock in irregular fragments. This last feature has been noticed commonly in other sandstones of this region. Muscovite is present, though it may be of secondary origin.

FIG. 17.—(× 100.) Section of type rock.

Specimen No. 11; locality, Engabao del Morro, Santa Elena, Ecuador; fine-grained sandstone (Tertiary).

In the hand specimen this rock has the appearance of a fine-grained, compact, laminated sandstone. Thin plates of white mica occur between the laminae, this mineral being one of the original constituents of the rock. The brownish color on the surface is due probably to a separation of iron carbonate, this being one result of tropical weathering. Under the microscope the rock is seen to consist of closely packed angular grains, most of which are quartz. Turbid feldspar of a plagioclase type also occurs sparingly, and it is possible that the decomposition of this mineral has formed part of the matrix of the rock. The presence of iron compounds, either in the form of an oxide or of a carbonate, with a few specks of magnetite, has resulted probably from the alteration of the ferro-magnesian minerals such as augite, evidences of which are seen in the groundmass. Most of the quartz grains are shattered, and muscovite in a fresh condition occurs commonly along the planes of bedding.

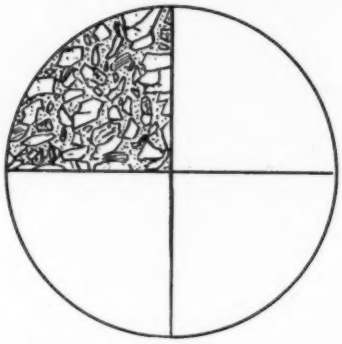


FIG. 18.—(× 20.) Section of type rock.

Specimen No. 12; locality, Cerros de Chanduy, Santa Elena, Ecuador; fine-grained sandstone (Tertiary).

This type is a gray compact sandstone, slightly calcareous. Under the microscope the rock consists of angular quartz grains, decomposed feldspars, white mica, secondary chlorite, and altered ferro-magnesian minerals. The ferro-magnesian minerals show serpentinization with a separation of fibrous chlorite and magnetite. Biotite occurs, but is rare. Apatite needles have been recognized in the groundmass, and well defined crystals of sphene are present in minor quantities. Traces of serpentinized olivine are found which show minute spherical aggregations of limonite. The rock appears to be in a fused or compressed condition with interlocking quartz grains bordered by chlorite. Secondary mica also is present.

FIG. 19.—(× 100.) Section of type rock.

Specimen No. 13; locality, Playas, Ecuador; fine-grained sandstone (Tertiary).

In the hand specimen this rock is slate-gray and is very compact and slightly calcareous. White mica is present in thin flakes which show fibrous sections under the microscope. Small fragments of volcanic lava are present as constituents, the groundmass of which is decomposed with a separation of brown iron oxide. Chloritic products form interstitial material. Under the microscope the rock also shows evidences of compression, the quartz grains appearing as a mosaic, with a distortion of the softer ingredients of the rock. In the figure it is seen that the quartz grains are impressed upon the included fragments of volcanic rock. Calcite occurs in a shattered form, and also occurs molded upon the quartz, thus being of secondary origin.

FIG. 20.—(× 100.) Section showing nature of groundmass.

Specimen No. 14; locality, Cerro Alto, Santa Elena, Ecuador; green indurated shale (Tertiary).

This type of altered shale is ordinarily found at a contact of a hypabyssal intrusion, the specimen under consideration having been collected alongside a dolerite dike. The shale is siliceous and appears to be locally crushed and contorted. Under the microscope the groundmass is too fine to be resolved satisfactorily. It is isotropic except for the presence of very fine angular fragments of quartz and plagioclase feldspar. Green glauconite occupies the casts of a few *Foraminifera*, though flakes of minute chlorite also are present. Volcanic ash probably forms the greater part of the groundmass, which is traversed by green veinlets. *Foraminifera, Radiolaria*, and sponge spicules occur commonly, *Globigerina* and *Textularia* being identifiable. A curious feature about the organic constituents is the fact that they, in common with the groundmass, are isotropic, suggesting that the rock itself has been altered completely, probably by pneumatolytic agencies.

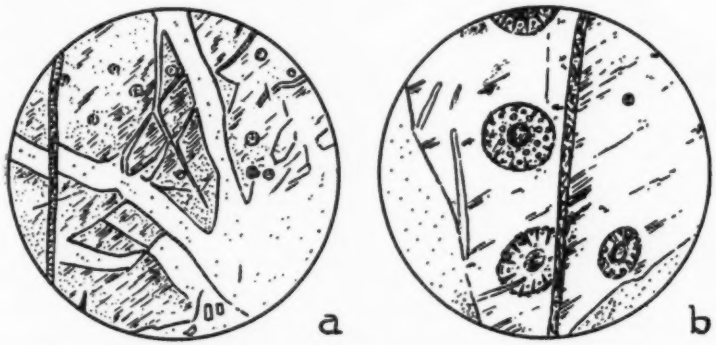



FIG. 21.—*a* (× 20), section of type rock; *b* (× 100), section showing sections of *Radiolaria*, et cetera.

Specimen No. 15; location, Cerro Alto, Santa Elena, Ecuador.

This specimen consists principally of a gray amorphous siliceous aggregation, with parallel banding of transparent quartz. The rock is traversed by many fracture planes, but at a late stage in its history was consolidated by secondary silicification into a homogeneous mass. Under the microscope the groundmass is seen to consist of finely divided, almost ultra-microscopic, opaque gray siliceous particles, with a few splinters of quartz and isotropic glass. Under crossed nicols the groundmass proper is isotropic; the transparent quartz veins, however, show a mosaic under polarized light. These veins are clearly of secondary origin, as they occupy faulted zones in the groundmass. This form of chert has the appearance of altered siliceous shale, the chief constituent of which is volcanic ash or dust. A few silicified *Foraminifera* and *Radiolaria* also are present in the section.

# GEOLOGICAL NOTES

## SUMMARY OF RESULTS OBTAINED TO DATE BY THE AMERICAN PETROLEUM INSTITUTE RESEARCH INVESTIGATION ON THE ORIGIN AND ENVIRONMENT OF SOURCE SEDIMENTS[1]

Project 4 of the American Petroleum Institute research program deals with the conditions under which source sediments of petroleum are accumulating to-day. This investigation is of special interest to the petroleum geologist, as its chief practical object is the ascertaining of criteria for recognizing source beds of petroleum. At present we do not know definitely what constitutes a source bed. We recognize that certain formations must contain mother rocks of oil, such as the Monterey formation of California, but how the members and individual layers in this, or any other formation, differ in their capacity as source beds we do not know. This is perhaps best exemplified by the fact that many core samples sent to us by geologists as probably being from good source beds contain so little organic matter that it is difficult to conceive of them as representing source beds.

The organic matter in source rocks in oil fields may have exhausted its possibility of producing oil; that is, the oil may have come from constituents no longer present in the deposits. Consequently, this project began by investigating recent sediments, for in fresh deposits all the organic substances from which petroleum is derived must be present. Special emphasis was laid upon marine and brackish-water sediments, as geological evidence indicates that most source beds had such an origin. The method of attack was first to study the organic matter as it reaches the sea bottom, then at successive depths beneath the surface of the deposits. Subsequent comparisons with rocks of different geologic horizons should enable us to trace the changes that occur in the source

[1]This paper contains preliminary results of an investigation on "The Origin and Environment of Source Sediments," listed as Project 4 of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by John D. Rockefeller. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council. Paper to be read before the Association at the New Orleans meeting, March 21, 1930. Manuscript received by the editor, February 3, 1930.

material from the time it first accumulates beneath the sea until it reaches its final rock state.

Our first procedure was to survey the amount of organic matter accumulating in different environments of deposition in the sea, so that the general distribution of organic matter in sediments might be ascertained and the richer areas might be selected for detailed study. Most of the deposits came from American coastal waters, but sediments from all parts of the world have been procured. There is scarcely an environment of deposition from which we do not have samples. The enthusiastic coöperation we have received from all sources has greatly facilitated our success in this undertaking.

The method of assaying the sediments was by dry destructive distillation. Although the amount of oil obtained by distillation forms only a minor part of the organic content, it nevertheless represents that part which can be made to become volatile and condense to a liquid oil. Therefore, it seems to be the least objectionable method of assaying the future potentiality of the sediments as source beds. However, we do not assume that oil is formed by such a process in nature.

Samples taken from well cores and regarded favorably as representing source beds by the geologists who forwarded them to us, were assayed in the same manner as the recent sediments. The yields were markedly similar. Many samples produced no oil, and only two, one from the Monterey of California and the other from the Eagle Ford of Texas, were richer than the best recent marine deposits. From this it seems clear that it is justifiable to derive inferences about past sediments from studies of recent deposits.

The results of the survey of modern sediments indicate that the more fine-grained the deposit the more likely it is to be a source bed, but just as is the experience with rocks of past geologic age, good potential source beds are rare. Sands contain so little organic matter that it is only under exceptional circumstances that they could be source beds. The limestone-forming deposits of Florida Bay and Cuba yielded two gallons of oil per ton on distillation, and are as rich as any marine deposit. Therefore it is evident that limestones as a class are eligible as source beds and that some limestones are probably good source beds. Many geologists are inclined to regard super-saline conditions as favorable environments for accumulation of source beds, but our work has not given much support to this view. A deposit from a lake rich in algae in northern Florida yielded 28 gallons of oil per ton and is evidently the mother rock of a rich oil shale.

As organic matter in marine sediments depends largely upon the supply of plankton in the overlying water, it follows that the farther a sediment is from shore the less likely it is to be a source bed. This of course does not apply to sandy zones near the beach where wave action inhibits the accumulation of organic matter in the deposits, or to shallow epi-continental seas in which sediments far from land might be rich in organic matter.

Although the supply of organic matter may be plentiful in the overlying water it does not follow that the sediments beneath will be correspondingly rich. Our work has shown that organic matter is concentrated in depressions or closed basins in the sea floor. It is surprising how many variations occur within a few miles in the organic content of some sediments, although the physical appearance of the deposits does not change. In the Channel Islands region of California, west of Los Angeles, the organic content of the sediments in the closed basins on the continental platform is nearly three times what it is on the adjacent slopes and ridges, but no appreciable difference in the physical character of the deposits is apparent. The organic content of the sediments on some of the divides between the basins is so low as to be of doubtful value as source material for oil, but within 10 miles the sediments rank with the richest marine deposits thus far found, and evidently are good potential source beds. Such contrasts may explain barren structures which adjoin commercial oil pools.

Having located a few regions in which the organic content was high, we collected from 50 to 500 pounds of sediment from these areas and treated it with carbon-tetrachloride to ascertain the amount of oily and hydrocarbon compounds it contained. No liquid hydrocarbons were found in any sample, but solid paraffines, organic pigments, and fatty acids, each to the extent of approximately five parts per hundred thousand, were present. Some liquid hydrocarbons might have been lost during the process of analysis, but control experiments to test this possible loss indicate that it could not have been greater than three parts per hundred thousand and probably was much less. Such quantities of hydrocarbons are not sufficient to make oil pools as we encounter them to-day. Although richer deposits may have formed in the past or may be forming to-day, the presumption from this evidence is that liquid petroleum does not form to any appreciable extent while the sediments are being deposited, but is produced later from material present at the time of deposition. However, the analyses show small amounts of some of the normal solid constituents of petroleum to be present in fresh deposits.

Organic sulphur compounds with as many as 30 parts per hundred thousand, and free sulphur ranging from 22 to 104 parts, were present in these sediments. Ether extracts of sediments of past geologic age are considerably greater than those of recent deposits of comparable organic content. This suggests the presence of free oil in the lithified sediments.

Carbontetrachloride extracts only a small part of the organic content, probably only 2-5 per cent. At present we are investigating the remaining organic matter, but we have not yet progressed sufficiently with the work to comment on the results. We have found cellulose and its simpler decomposition products in only very small amounts in marine sediments of all types, and even less in deposits of past geologic age. The scarcity of these substances tends to invalidate the theories which maintain that petroleum arises from in-washed higher plant débris. Nitrogen seems to be a fairly good index of the organic content, but the nitrogen content is considerably lower in past sediments than in recent.

What we are presenting here is only a progress report. We have much yet to do, but already we have placed some things on a firmer basis than they were before. The most important of these are: (1) that it is improbable that petroleum forms in sediments at the time of, or shortly after deposition; (2) that the organic content of a deposit, therefore its potentiality as a source bed, may differ considerably within a short distance, although its physical appearance does not change; and (3) that depressions in the sea floor favor the concentration of organic matter.

PARKER D. TRASK
*Research Associate, American Petroleum Institute*

PRINCETON, NEW JERSEY
January 30, 1930

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## BASEMENT ROCKS IN SHELL-HUMPHREYS WELL, PECOS COUNTY, TEXAS

The Shell-Humphreys University No. 1, Block 26, Pecos County, Texas, is of particular interest in that it is the first test in the West Texas Permian basin to encounter rocks of the Basement complex below the Permian limestone section. The test is situated near the crest of the well known Fort Stockton "high" on which, heretofore, the deepest of the many borings had attained a depth of only 4,500 feet, and was abandoned in limestone. At a depth of 785 feet, after passing through many brown dolomitic limestone lenses distributed through the 400 feet

of overlying anhydrite, the Shell test entered the persistent limestone section. A heavy flow of sulphur water, estimated at more than 10,000 barrels a day, was found only a few feet below the top of the limestone, and many other water horizons were encountered throughout the limestone section without any showings of oil or gas. Between the depths of 785 and 4,250 feet the predominant rock is a white, cream, or light tan dolomitic limestone, generally uniform throughout, although here and there a little bentonitic shale or fine-grained sand is present. Between the depths of 4,250 and 4,660 feet gray bentonitic shale, ranging from small amounts to 80 per cent, occurs in the limestone, but the whole section is regarded as Permian in age. Between the limestone and basement rocks encountered at 4,750 feet is about 100 feet of detrital material consisting chiefly of red and green shale, but containing also small amounts of angular and rounded sand and weathered limestone fragments.

The character of the cuttings from 4,750 feet to the bottom of the hole at 5,204 feet indicates that several rock types are represented in the section. Most of the cuttings are very fine-grained, due to the slow drilling in a hole full of water, and they are masked by iron-rust particles from the bit. Although the progress through this section varied from 6 to 25 feet a day, most of the runs, on account of the wearing of the bit, were of only 2 or 3 feet. Where runs of more than 3 feet could be made the rock particles were larger, and some fragments were obtained that showed two or more minerals, but no fragments were recovered that were large enough to make thin sections for petrographic study.

Some of the coarser cuttings distributed throughout the section are white to light gray, and tinted in different shades of pink, due to different proportions of pink feldspar; other cuttings are dark gray to brown, resulting from differing contents of dark minerals, such as biotite, hornblende, hematite, and chlorite. The lighter-colored samples resemble cuttings from granitic rocks, while the darker samples resemble cuttings from metamorphic rocks. Microscopic examination, however, shows that angular glassy quartz predominates in all of the samples of cuttings, and in the light-colored grains its proportion ranges from 74 to 86 per cent. In these same samples the feldspar content ranges from 12 to 25 per cent, the greater percentage of feldspar being obtained in the cuttings near the bottom of the hole. The feldspar consists largely of microcline, but orthoclase and plagioclase also are present. The feldspar is fresh and unaltered. The darker minerals include biotite, hornblende, hematite, and chlorite. Between the depths of 5,045 and 5,060

feet the samples are dark green in color, and the texture is coarsely granular. Hornblende and chlorite are plentiful in the samples, associated with a black mineral that is probably hematite. In other places biotite is the most plentiful dark mineral and commonly shows in small hexagonal basic sections.

The conclusion is reached that this rock is largely a metamorphosed sandstone, cut by veins and stringers of pegmatite or aplite. The high percentage of quartz and the low content of feldspar in the samples and the rather high rate of drilling progress indicate that the rock is not wholly of igneous origin.

E. L. JONES, JR.
RUSSELL C. CONKLING

SHELL PETROLEUM CORPORATION
SAN ANGELO, TEXAS
December 11, 1929

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## ORIGIN OF CAVE-INS IN WALLACE COUNTY, KANSAS[1]

Since the sudden subsidence near Sharon Springs in 1926, this and other local subsidences of Wallace County, Kansas, and adjacent area have attracted much attention from geologists as well as from the general public.

Two explanations of the origin of these subsidences have been offered: one in 1926, by R. C. Moore, state geologist of Kansas,[2] and the other in 1929, by W. L. Russell.[3] Moore sees the cause of subsidence in origination of large cavities in the Niobrara chalk, which underlies the locally outcropping rocks, Pierre shale, and "Mortar beds" of the Ogallala formation. He suggests that the cavities are due to local solution of chalk caused by underground water circulation.

Russell, on the contrary, believes that his observations in Wallace, Logan, and other counties in western Kansas exclude the possibility of underground chalk solution "because of the impervious and relatively insoluble nature of the chalk, and because the solution could take place only at the outcrop." He suggests that large caverns in the Niobrara formation could be produced by tensional faults, "the thinness of the overlying strata" together with "the relatively rigid character of the

[1]Published by permission of the state geologist of Kansas.

[2]Raymond C. Moore, "Note on Subsidence Near Sharon Springs, Wallace County, Kansas," *Geol. Survey of Kansas Bull. 11* (1926), p. 96.

[3]William L. Russell, "Local Subsidence in Western Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13 (1929), p. 605.

Smoky Hill chalk" providing sufficient conditions for accidental caves between the walls of a fault, the walls of the cavities being "sufficiently strong to resist the pressure for a considerable time." The time for the occurrence of such cavities dates back, according to Russell, to "late Pliocene or early Pleistocene," when the tensional faulting of the Ogallala occurred. This means that the walls of the supposed caves, produced by tensional faulting of this time, resisted the pressure of overlying rocks for 500,000-1,000,000 years of Pleistocene and Recent times before collapsing.

If large cavities in underground strata of Niobrara chalk could originate in connection with faulting of post-Ogallala (early Pliocene) time, the sudden subsidence over these supposed "tensional" cavities hundreds of thousands of years later seems to be mechanically unsound, unless some sort of gradual weakening of the walls or of the roof of the cavities occurred. However, if destructive undermining work of ground water is completely excluded, as suggested by Russell, there seems to be no agency which would gradually weaken the walls and cause their final collapse. No such agency is suggested. The daily change of temperature, which is an important factor in disintegration of the rocks on the surface, certainly has no effect on rocks buried hundreds of feet below the surface. There is perhaps a slight chance that the walls of an underground cavity in the Niobrara might yield very gradually with time, if the pressure of overlying strata was just a fraction higher than the elastic limit of the Niobrara rocks. However, even if such a condition occurred at the time of origin of the "tensional" voids, the gradual erosion of overlying beds would soon change these conditions, decreasing the overlying load to a point well below the elastic limit of the cavern's walls. As a matter of fact, the thickness of overlying beds since Ogallala time has been reduced to about one-half of the original thickness of the beds above the underground chalk of the Smoky Basin cave-in. The thickness of the Pierre shale overlying the Niobrara chalk at the Smoky Basin cave-in is now hardly more than 350 feet—probably less—although at the time of faulting there was not less than 100-150 feet of additional thickness of shale, now eroded away, and above the shale 200-350 feet constituting the Ogallala formation.

As noted by Russell, there is a fault which can be seen in the north wall of the Smoky Basin cave-in, cutting the area of present subsidence about in the middle. The fault can readily be recognized by the change of color and some other lithological features, such as a profusion of fish scales and concretions on the northwest, or downthrown, side of the fault.

However, the presence of this fault can hardly help the "tension cavities" theory. This fault seems to be truly a normal or tension fault, but the plane of faulting is much inclined toward the northwest (45°-60°), while the starting place of the subsidence is on the east side of the present basin, or east of the surface line of the fault (Fig. 1).

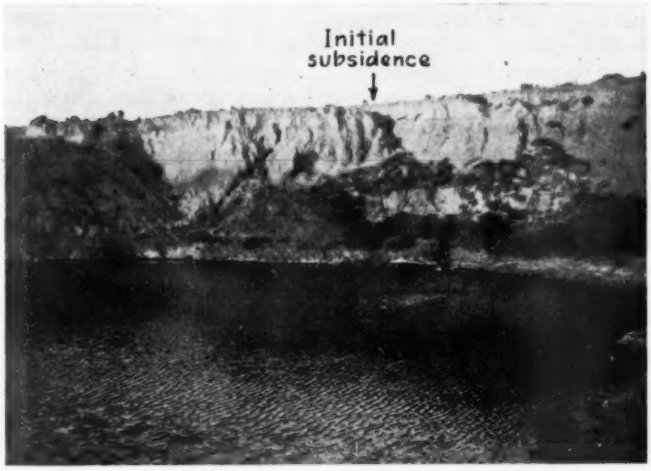


FIG. 1.—Photograph showing fault and point of initial subsidence.

If the underground dip of the fault does not differ appreciably from the observed surficial dip, which is only a natural extrapolation of surficial observation, then the place of the supposed "tensional cavity" in the Niobrara chalk will be 200 feet or more west of the center of the present cave-in basin and still farther from the initial place of subsidence.

Figure 2 shows the eccentric position, relative to the Smoky Basin cave-in, of the nearest possible tension-fault cavity in the underground beds of Niobrara chalk. The overlying Pierre shale is shown to be 350 feet thick, according to the estimation by the writer. The allowance of 700 feet of shale above the cavity, as suggested by Russell, would place the nearest possible tension-fault cavity 250 feet farther from the subsidence.

The position of a cave directly below the initial subsidence is shown on the sketch (Fig. 2). According to the laws of rock subsidences as

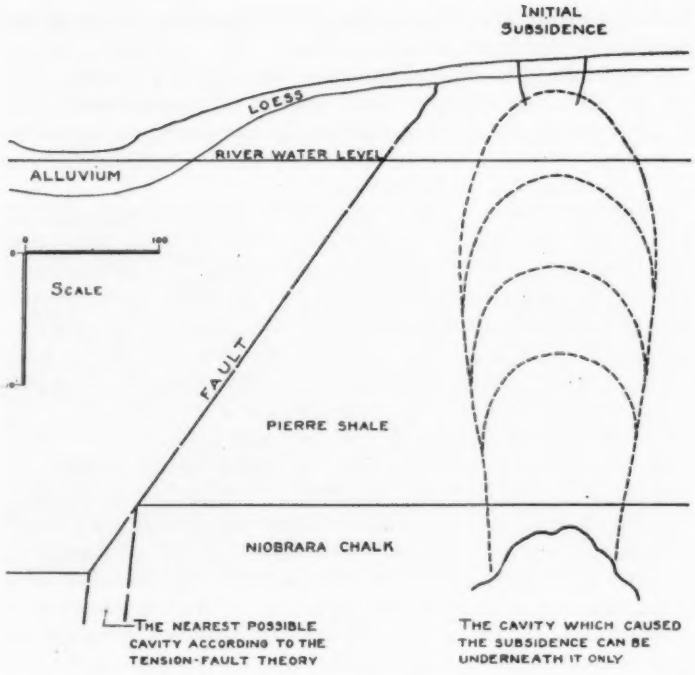


FIG. 2.—Diagrammatic sketch of Smoky Basin cave-in. Horizontal and vertical scale in feet.

established by J. Callon, H. Fayole, and others, based on extensive studies in mines, a subsidence over an undermined area of horizontally stratified rock is propagated in a more or less straight vertical direction. A system of subsequently developed dome-like cracks is formed, and along these cracks parts of strata tear off and fall down.

The Cretaceous formations at the Smoky Basin cave-in are nearly or quite horizontal; therefore, no other than a vertical cave-in over an underground cavity in these formations may reasonably be inferred. The cave is presumably located in the top layers of Niobrara chalk, but it could be formed equally well in deeper layers of Niobrara. The vertical scale of the sketch is not exaggerated.

The writer is inclined to think that the fault of the Smoky Basin cave-in might be an indirect cause for the occurrence of the subsi-

dence by helping the surface waters to enter the chalk through fissures developed in connection with the faulting.

Observations in coal mines show that faults are rarely quite dry, but ordinarily a large or small amount of surficial water moves along the fault planes. The coal-bearing formations are commonly fairly argillaceous, a condition, however, which does not generally lead to a complete sealing of the fault fissures.

The lower part of the Pierre shale which overlies the Niobrara chalk in the area of the Sharon subsidence does not consist of clayey shale alone, but is made of intercalating beds of clayey shale and dark gray chalky shale with a seemingly low density. It seems to be quite possible, if not probable, that zones of cracks or breccia which might develop in places along the fault provided channelways for the circulating surficial waters which could descend to the Niobrara chalk and start a solution cavity, which is common in limestones elsewhere.

It seems clear that whether underground water in the Niobrara chalk migrated from distant outcrops of the formation or descended directly through the fissures along a fault zone, the solution of the chalk would not be uniform. There were doubtless more soluble and probably more pervious parts of the chalk where the larger caves were presumably formed. The Niobrara formation does not consist of uniform chalk, but of chalk and clay mixed in different proportions. The underground water does not seem to permeate the whole of the Niobrara formation and furthermore does not necessarily fill up either the particular paths along which it moves or the caves caused or enlarged by this circulation. Therefore a subsidence over such caves may have initially a perfectly dry bottom, the amount of water in the cave being only enough to fill the space between the blocks and fragments of the collapsed roof.

M. K. ELIAS[1]

STATE GEOLOGICAL SURVEY
LAWRENCE, KANSAS
January, 1930

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## SMALL *EN ÉCHELON* FRACTURES IN SANTA BARBARA COUNTY, CALIFORNIA

Along the low cliffs which border Burton Mesa north of the mouth of Santa Ynez River, a part of the lower cherty facies of the Monterey shale is well exposed. The strata have low dips, in the main, with many small anticlines and synclines, many fractures of all imaginable types,

[1]Introduced by R. C. Moore.

and an almost unlimited number of joints belonging to many systems. The area is excellent for the study of small-scale examples of many structural features. The following note is a description of one such example of a type of fracture that has been widely discussed in recent years.

Figure 1 is from a photograph of a small promontory projecting oceanward obliquely to the trend of the shore line. Overlying the chert

FIG. 1.—Promontory of cherty Monterey shale, capped by dark gray dolomitic limestone with *en échelon* cracks. Looking southwest.

on a part of the flat upper surface of the promontory is a bed of fine-grained dolomitic limestone (darker gray) several inches in average thickness. This bed is itself imperfectly stratified into a thicker lower and a thinner upper member. The lower limestone member is cut by regular, parallel fractures several inches apart. In places these fractures cut through to the upper surface of the upper member; in others their course is suggested by the presence of small *en échelon* cracks, each 2-4 inches long, and several to the foot (Fig. 2). The average trend of the major fractures is N. 10°-15° E.; that of the minor fractures, about N. 50°-60° E. The minor fractures, in other words, make an angle of approximately 40° with the major fractures.

Some of the minor fractures gape a few tenths of an inch at the surface. Others are closed, but are made conspicuous by a decolorizing of the limestone for about a tenth of an inch on each side. The cause of this phenomenon is not evident, but it can be duplicated by leaching the surface of the limestone with dilute hydrochloric acid for a minute

FIG. 2.—*En échelon* cracks in limestone. The camera was held vertically.

or two. There is no vertical displacement along either the major or the minor fractures. In connection with the latter, however, its absence may be due to abrasion and solution of the surface. The fact that the minor cracks lie along the crests of low rounded ridges clearly suggests a worn and corroded surface rather than an unaltered bedding plane.

By analogy with other series of *en échelon* faults and fractures, and with experimental evidence and theoretical considerations, it may be supposed that these small cracks were produced by a slight shearing movement along the major fractures, the westerly block in each case having moved northward. The writer has no desire, however, to exclude other possible interpretations.

R. D. REED

THE TEXAS COMPANY
LOS ANGELES, CALIFORNIA
January 28, 1930

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## HIGHEST TAYLOR CHALK IN JACKSONVILLE, TEXAS, EMBAYMENT

The writer's attention has been called to a chalk in Reiter *et al.* Busby No. 1, on the Marquez salt dome in Leon County. This chalk was drilled from a depth of 2,595 feet to a depth of 2,623 feet and cored from 2,601 to 2,609 feet.

This chalk is exposed 1 mile north of the well on top of the salt dome. The edge of the surface exposure was determined by James A. Waters, of the Sun Oil Company. The core from 2,601 to 2,609 feet carries the same foraminiferal assemblage. This chalk is easily identified by the presence of *Lituola taylorensis*, Cushman and Waters.[1]

Shortly after noticing the chalk in the well at Marquez, the writer was watching the drilling of the E. M. Strange well No. 1, 3 miles west of Wortham, Texas. The driller reported hard shale from 1,523 to 1,552 feet. Core was taken from 1,542 to 1,552 feet. This was soft chalk of Taylor age, as determined paleontologically by the writer.

There is good exposure of this chalk 3 miles northwest of Cooledge on the main road to Hubbard in Limestone County. At this exposure the chalk is a white marl.

Recently the writer's attention has been called to an unknown chalk in many wells in Freestone County, Texas. The writer is very sure that the chalk in all these places is the same and that it is a chalk at the top of the Taylor formation of Upper Cretaceous age.

The position of this chalk ranges from 500 to 600 feet below the top of the Nacatoch sand, and approximately 1,300 feet above the top of the Austin chalk. It is fairly easy to identify this chalk in the well records because the overlying Navarro is sand or sandy shale and the upper part of the Taylor is calcareous shale or chalk.

Mr. Waters and the writer propose the name "Cooledge chalk" for this highest Taylor chalk.

W. A. REITER

MEXIA, TEXAS
January 18, 1930

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## SECOND CONGRÈS INTERNATIONAL DE FORAGES

The writer had an opportunity to attend the second International Drilling Congress held in Paris and other parts of France, September 15-31, 1929. One may call this organization the European counterpart of the American Association of Petroleum Geologists. F. G. Clapp and the writer were the only Americans attending.

This congress was opened in the forenoon of September 15 in Paris. In the afternoon excursions were made to Versailles and other places in the vicinity of Paris.

[1] *Contributions from Cushman's Laboratory*, Vol. 5, Pt. 3.

On September 16 a business session was held in the forenoon, papers were read in the afternoon, and a banquet was given in the evening.

On September 17 papers were read in the forenoon and afternoon, and in the evening a reception to the members was given by the Chamber of Commerce of Paris.

On September 18 papers were read in the forenoon, and in the afternoon the Congress was closed. In the evening, a reception was given to the members by the mayor of Paris.

On September 19 the members left Paris for Nancy, where they engaged in sightseeing, and participated in a reception given by the Chamber of Commerce.

On September 20 a special train was taken from Nancy to Homécourt. The local works of the Compagnie des Forges et Aciéries de la Marine were visited, and the company gave the visitors a reception. In the evening a special train carried the members to Strasbourg, arriving there before midnight.

On September 21 some members visited the Pechelbronn oil mines and others visited the Strasbourg petroleum colleges. In the evening a fine banquet was given to the members by the Chamber of Commerce of Strasbourg and the Pechelbronn Company.

On September 22 an excursion was made into the Vosges Mountains southwest of Strasbourg to the Monastery Sainte-Odile and other places.

On September 23 the congress traveled from Strasbourg to Mulhouse and visited the potash mines there, and in the evening attended a banquet given by the Société Commerciale des Potasses, which ended the excursion and entertainments.

The papers submitted were read in French, German, or English, but all the résumés of these papers were printed in French. They covered all subjects pertaining to drilling, besides the geological aspects of present and probable oil fields of Europe. When printed and published in one volume, these papers will be valuable to petroleum geologists interested in Europe.

Regret was expressed by many members that the United States had not taken a larger part in the congress, since all European members were anxious to learn by personal contact, rather than by reading, what we are doing in the United States in the petroleum industry.

Rumania and Poland had the largest delegation at the congress.

F. O. MARTIN

LOS ANGELES, CALIFORNIA
January 25, 1930

## WORLD ENGINEERING CONGRESS

Having represented the American Association of Petroleum Geologists as an official delegate at the World Engineering Congress, held in Tokio, Japan, in October and November, 1929, the writer submits this report.

The writer took the longest route to Japan, traveling first to different countries of Europe; then from Berlin to Moscow and over the Trans-Siberian railroad to Wladiwostok; by steamer to Tsuruga, Japan; and by railroad to Tokio.

The delegates were cordially received and treated with the utmost kindness and overwhelmed with hospitality by all ranks of the Japanese people, from the emperor to the school children. Some one calculated that we had received invitations to 91 social functions in 10 days. Before, during, and after the congress, excursions were conducted to practically all the interesting places of Japan: scenic, technical, and industrial.

The languages of the congress were Japanese and English, but all Japanese papers were printed also in English. Nearly all nations of the world were represented. The United States delegation was the largest, consisting, with ladies, of more than 400 persons.

The World Power Conference held sessions at the same time, and at its sessions also papers of interest to the petroleum industry were read. The following list includes the papers of interest to the petroleum industry which were read at either the World Power Conference or the World Engineering Congress.

"Petroleum," by Mark L. Requa (United States)

"Treatment of Oil Shale," by T. M. Davidson (United States)

"Petroleum Resources of Japan," by Yoshinosuke Chitani (Japan)

"Transition of Oil Consumption for Power Use in Japan," by Keizaburo Hashimoto (Japan)

"Synthetic Fuels and Lubricating Oils," by A. W. Nash (Great Britain)

F. O. MARTIN

LOS ANGELES, CALIFORNIA
January 27, 1930

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## CORRECTION

In "Geophysical Methods of Prospecting in the Union of Socialistic Soviet Republics," by B. Numerov, published in the January *Bulletin*, in the title of Figure 2, page 97, the words "productive wells" should be changed to *prospect holes*.

# DISCUSSION

## MAGNETOMETER STUDY OF CADDO-SHREVEPORT UPLIFT, LOUISIANA

The paper by William M. Barret entitled "Magnetometer Study of Caddo-Shreveport Uplift" presents frankly the difficulties encountered in interpreting magnetic anomalies. Only by recognizing all the possible factors affecting the resultant picture can we eliminate all but the most probably predominant influence in a certain area. Correct geologic interpretations of magnetic charts must depend on the possibility and success of this process.

Regarding the interpretation of negative anomalies or seeming effects of local north-seeking polarity, Barret says:

> The rapid dip of the formations on the north boundary of the Caddo-Shreveport uplift, in which region the edges of the major and minor uplifts practically coincide, might account for the localized negative feature of Figure 3.

Later he says:

> The localized regions of north and south polarity may be ascribed to.....induced polarization of the tabular mass.

And again:

> As a plausible explanation of the apparent polarization we may suppose that the north polarity of the magnetic profile.....is produced by the nearer approach to parallelism with the earth's resultant field, of the plunging tabular forms on the north end of the uplift.

It seems to me that both theoretical considerations and practical results in my experience point to the opposite.

Whether a tabular mass of high permeability is regarded as disturbing the magnetic field in direction and intensity, or the disturbance is regarded as caused by induced polarity in the mass, will not the resulting effect in vertical-intensity anomaly be similar?

Inasmuch as a tabular mass of the basement rocks must be considered as having a considerable vertical dimension — therefore a considerable dimension parallel with the earth's field—will not south-seeking polarity be induced near the upper surface of the mass, and north-seeking polarity tend to localize at remote depth? From the standpoint of high permeability, although the total-intensity anomaly will show a peak over the symmetrical center of the tabular mass, is there not a tendency to form a secondary high peak of vertical-intensity anomaly over the shoulder or top of a north flank? Surely just over this north edge the direction of the earth's field will tend to become steeper toward the high-permeability medium, which will result in an increase in the vertical-intensity component at the expense of the horizontal component, and vice versa at the south shoulder. Actual observations of both horizontal and vertical anomalies over strong magnetic "highs" and actual anomalies found over

known buried igneous ridges have been found to agree with these theoretical expectations.

These considerations, however, supply no explanation of a negative anomaly or north-polarization effect, but so far the buried ridge or tabular mass has been regarded as of uniform permeability. Should there be a horizontal disposition of beds or zones capping the buried "high" or tabular igneous mass and having higher permeability than the adjacent rocks, would not the horizontal component of the earth's field tend to induce horizontal polarity in them? We should then find north-seeking polarity or a negative anomaly at the north flank, or northern termination, of such beds or zones, and a south polarity at the southern edge. This tendency to develop south polarity at the southern edge would be slightly counteracted by the tendency of the permeability effect of the tabular mass as a whole to develop a vertical-intensity "low" over the south shoulder. The predominance of this polar effect will be somewhat affected by the relative permeability of the rocks involved, but more by the comparative nearness of the cap rocks to the surface. This predominance of south polarity at the southern edge, in conjunction with the total-intensity peak at the center of the uplift, will result in a vertical-intensity peak shifted somewhat south of the symmetrical center of the uplift. In the Caddo-Shreveport uplift the regional magnetic high anomaly due to the Sabine uplift as a whole would, as Barret points out, also help to shift this vertical-intensity peak toward the south. The tendency to develop north polarity at the north edge, acting against and predominating over the tendency to develop a secondary high vertical-intensity peak over the northern shoulder of the tabular mass as a whole, would tend to shift the negative-anomaly area farther down the flank toward the north.

This is approximately the magnetic picture shown by Mr. Barret, and I agree with his interpretation, although I reach this conclusion by different reasoning, based on the conception that the anomalies are probably chiefly due to a predominating polarization effect in beds or zones at or near the top of the basement "high" which caused the local Caddo-Shreveport structure.

DOUGLAS M. COLLINGWOOD

SUN OIL COMPANY
DALLAS, TEXAS
December, 1929

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AUTHOR'S REPLY

Three hypotheses were advanced by the writer to account for the areal pattern of the resultant vertical-intensity anomalies associated with the Caddo-Shreveport uplift. Briefly, these hypotheses were based upon *polarization, attitude of tabular forms,* and *differential permeability.*

According to Collingwood these theories do not furnish a satisfactory explanation of the observed negative anomalies. He states:

> It seems to me that both theoretical considerations and practical results in my experience point to the opposite.

Following this terse negation he proceeds to explain the anomalies on the basis of *polarization*, one of the suggestions previously advanced by the writer, who said:

> The localized regions of north and south polarity may be ascribed to differential permeability or to induced polarization of the tabular mass, the latter interpretation being supported by empirical data collected from surveys of somewhat similar, isolated, geologic disturbances occurring in the same general geographic region as the uplift.

We are naturally led to the inference that some misconception exists concerning polarization. This supposition is confirmed upon an analysis of the following extract from Collingwood's discussion.

> Whether a tabular mass of high permeability is regarded as disturbing the magnetic field in direction and intensity, or the disturbance is regarded as caused by induced polarity in the mass, will not the resulting effect in vertical-intensity anomaly be similar?

Because the two conditions propounded are fundamentally identical, we may assuredly answer in the affirmative. It is difficult to conceive of a highly permeable mass being introduced into the region of a magnetic field without the body becoming polarized. A most significant fact, ignored by many geomagnetic investigators, is that, by definition, *every magnetized body is polarized*.

The conception of polarization is one of the most helpful and convenient theories for the practical interpretation of magnetic anomalies, but it is not without difficulties. If our assumptions are granted sufficient latitude, it is an assured truth that virtually every group of anomalies may be reconciled on the basis of polarization.

We may logically infer that the principal factors influencing the polarizing effect are the strength of the magnetizing field, the shape, distribution, attitude, and mineral composition of the formations, and the nature of the surrounding media. Should this analysis fail to explain a specified set of conditions, we may assume that the individual rock bodies differ in residual magnetism, or that the embedded mass exhibits more than two definite poles, for we know that under certain laboratory conditions it is possible to produce more than two poles in particular specimens.

The pliant nature of the conception of polarization is its most formidable attribute.

Collingwood's interpretation, constructed on the principle of polarization, assumes a magnetized tabular mass of the basement rocks, polarized in the vertical plane, and horizontal beds or zones capping the deeper-seated mass and polarized in the horizontal plane, to be the cause of the observed reactions. His conclusions are justifiable if we admit the validity of his assumptions.

However, could we not omit the presence of the deep-seated reaction and trace the resultant anomalies to the horizontally disposed beds with equal soundness and facility? This interpretation would exclude as factors the complex interlinking of flux between dual reactions as well as the "shielding" or "screening" action of the relatively shallow formations which overlie the deeper disturbance.

WILLIAM M. BARRET

SHREVEPORT, LOUISIANA
February 3, 1930

## *EN ÉCHELON* FAULT BELTS

Melton's paper in the January *Bulletin* on the "Age and Tectonic Effects of Ouachita Orogeny" is an interesting discussion of an important problem. In his section on "*En Échelon* fault belts" he says, "grave doubts as to the reality of *en échelon* belts are prompted merely from a study of the state geologic map." A study of the *Geologic Map of Oklahoma*, on which there is nothing to differentiate between accuracy of detail and guess-work, seems an insufficient basis for his conclusions. He grants the existence of faults, but discounts the *en échelon* arrangement and grouping into belts.

Intensive detailed field mapping by many competent geologists in Osage, Creek, Pawnee, Payne, Lincoln, Seminole and Okfuskee counties, Oklahoma, definitely establishes the existence of belts of *en échelon* faults, many of which are believed to have a deep-seated origin. Melton points out that many faults exist in the plains that have not been mapped. Probably this is true in areas not yet detailed. It is also possible that faults of small throw are present between the *en échelon* fault belts, but this does not disprove the fact that there are definite belts of *en échelon* faults extending for many miles in a certain direction.

It will require more than a mere study of the *Geologic Map of Oklahoma* to offset the extensive detailed mapping.

FRANK R. CLARK

TULSA, OKLAHOMA
February 13, 1930

# REVIEWS AND NEW PUBLICATIONS

"Oil and Gas Fields in Poland." Edited by K. TOLWINSKI. *Polish Geological Survey Carpathian Station Bull. 18* (Warsaw, Poland, 1929). 112 pp., 22 figs.

This small volume, published by the Polish Geological Survey in Polish and in French, describes in very considerable detail several Polish oil fields, the text being accompanied by excellent illustrations showing geological maps and cross sections.

The detached fields are discussed individually; those which are grouped together are discussed first as a geological unit and next individually. The individual descriptions cover in detail the following factors: geological structure, producing horizons, physical characteristics of crude oils, water horizons, chemical characteristics of waters, productivity of oil wells and their life, production of individual fields by years, gas horizons and their productivity, future possibilities of individual fields and their history.

The fields discussed in this report include: Sloboda Rungurska, Kosmacz, Pasieczna, Bitkow, Majdan, Rypne-Duba, Nahujowice, Schodnica, Urycz, Opaka, Orow, Lopianka, Spas on Czeczwa, Witwica, Pobuk-Synowodzko Wyzne, and Strzelbice.

BASIL B. ZAVOICO

TULSA, OKLAHOMA
February 13, 1930

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*Geologic Map of the World.* Edited by FRANZ BEYSCHLAG (Berlin W. 35, Schöneberger Ufer 12 a). Scale 1: 15,000,000; in 12 sheets, each 25 by 31 inches.

Although this is a private undertaking by the former president of the Prussian Geological Survey, it has been prepared with the scientific and technical assistance of that Survey. All available geologic information seems to have been carefully compiled and correlated. Areas where information is doubtful or lacking have been left blank.

The geologic formations are shown in colors conforming to general usage, with 21 divisions for sedimentary, and 9 for igneous rocks. Ocean depths are shown by the 200-meter contour and the 1,000-meter contour and its multiples. The title and legend are in German, French, English, and Spanish. Names of cities and rivers are mainly in the language of the respective countries; other geographic names are in German. Political boundaries are omitted.

The first installment, of 4 sheets covering the northern part of the world, has been issued; the second and third installments are to be issued before the

end of 1930. The map is to be sold only in complete sets of 12 sheets and legend, the subscription price being 150 gold marks, or £7.10.0 (about $36.00).

GERALD A. WARING

TULSA, OKLAHOMA
February 20, 1930

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## RECENT PUBLICATIONS

### CALIFORNIA

"Santa Fe Springs Oil Field," *Summary of Operations, California Oil Fields*, Dept. of Nat. Resources, Division of Mines and Mining (San Francisco, California, January, 1929), Vol. 14, No. 7. 21 pp., 7 pls.

### FRANCE

"Les Domes de Soufre," by Ch. Finaton. *Revue Pétrolifère* (Paris, January 18, 1930), pp. 81-84, 7 photographs, 1 geologic map.

### GENERAL

*Deposition of the Sedimentary Rocks*, by J. E. Marr. (University Press, Cambridge, England, 1929). 245 pp. Price, 7 s. 6d. net.

*Fiftieth Annual Report of the Director of the Geological Survey* (for the fiscal year ended June 30), *1929*. George Otis Smith, Director U. S. Geol. Survey (Washington, D. C., December, 1929). 87 pp., 1 pl.

### GEOPHYSICS

"The Status and Importance of Isostasy," by William Bowie. *Mining and Metallurgy* (New York, N. Y., February, 1930), pp. 93-95.

### JUGOSLAVIA

*Geokemija Joda* (Geochemistry of Iodine), by Stanko S. S. Miholić (Beograd, 1929). Contains map of oil seepages in Jugoslavia and a bibliography of 187 titles. 49 pp., 9 figs.

### MICHIGAN

"The Middle Devonian Traverse Group of Rocks in Michigan, A Summary of Existing Knowledge," by Erwin R. Pohl. *Proc. U. S. Natl. Mus.* (Washington, D. C., January 10, 1930), Vol. 76, Art. 14, pp. 1-34, Pls. 1, 2.

### OKLAHOMA

The Oklahoma Geological Survey, Norman, Oklahoma, announces the following publications.

"Oil and Gas Geology of Johnston and Murray Counties," by F. A. Melton. *Bull. 40-LL*. Price, $0.30.

"Oil and Gas Geology of Cotton County," by W. F. Cloud. *Bull. 40-MM*. Price, $0.30.

"Oil and Gas Geology of Mayes, Ottawa, and Delaware Counties," by H. A. Ireland. *Bull. 40-NN*. Price, $0.30.

"Sedimentation in the Anadarko Basin," by A. J. Freie. *Bull. 48.* Price, $0.57.

"The Dolomites of Western Oklahoma," by G. G. Suffel. *Bull. 49.* Price, $0.57.

"Foraminifera from the Atoka Formation of Oklahoma," by J. J. Galloway and Charles Ryniker. *Circular 21.* Price, $0.30.

WYOMING

"The Varves and Climate of the Green River Epoch," by W. H. Bradley. *U. S. Geol. Survey Prof. Paper 158-E* (Supt. Documents, Washington, D. C.), pp. 87-110, Pls. 11-14, Figs. 14-15. Price, $0.15.

"The Flora of the Frontier Formation," by E. W. Berry. *U. S. Geol. Survey Prof. Paper 158-H* (Supt. Documents, Washington, D. C.), pp. 129-35, Pls. 20-21. Price, $0.05.

# THE ASSOCIATION ROUND TABLE

## MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

### FOR ACTIVE MEMBERSHIP

Carl C. Addison, Calgary, Alta., Canada
B. F. Hake, S. E. Slipper, Theodore A. Link

John Andrew Allan, Edmonton, Alta., anada
J. O. G. Sanderson, Theodore A. Link, S. E. Slipper

B. Howard Bentley, San Angelo, Tex.
C. A. Russell, R. E. Rettger, Cary P. Butcher

Charles W. Ellison, Cushing, Okla.
Boone Jones, Charles C. King, O. H. Borst

Charles E. Erdmann, Denver, Colo.
Clinton R. Stauffer, W. H. Emmons, C. E. Dobbin

Fritz Kaselitz, Houston, Tex.
Paul Weaver, L. P. Garrett, W. F. Henniger

Lloyd R. Manning, Fort Worth, Tex.
D. G. Barnett, D. M. Wallace, George D. Morgan

Henry Garrett Martin, Maracaibo, Venezuela, S. A.
Chester A. Baird, Edward S. Bleecker, C. M. Crebbs

Albert Nelson Murray, Tulsa, Okla.
W. E. Bernard, A. L. Beekly, Frank R. Clark

Charles Glenn Staley, Santa Fe, N. M.
F. S. Prout, Joseph E. Morero, C. T. Griswold

Benjamin L. Thorne, Calgary, Alta., Canada
J. S. Stewart, P. D. Moore, Theodore A. Link

### FOR ASSOCIATE MEMBERSHIP

Overton B. Banks, Beaumont, Tex.
P. S. Justice, R. W. Pack, Lon D. Cartwright, Jr.

Harry L. Berry, Tulsa, Okla.
V. E. Monnett, C. E. Decker, G. E. Anderson

Neal J. Bingman, Dallas, Tex.
Leonard W. Orynski, H. J. Hawley, K. H. Crandall

Thomas J. Burnett, Tyler, Tex.
G. Moses Knebel, E. A. Wendlandt, H. J. McLellan

D. Harold Cardwell, Tyler, Tex.
Wallace C. Thompson, Francis E. Heath, James A. Waters
Henry C. Cortes, Houston, Tex.
S. A. Thompson, Dilworth S. Hager, Alexander Deussen
Francis R. Coryn, Fort Worth, Tex.
Alan Bruyere, B. E. Thompson, R. J. Metcalf
John W. Cushing, Calgary, Alta., Canada
F. W. Rohwer, S. E. Slipper, Theodore A. Link
Edwin A. Dawson, Wichita, Kan.
A. W. Lauer, J. N. Troxell, Anthony Folger
Barney Feagin, Jr., Tulsa, Okla.
V. E. Monnett, C. E. Decker, G. E. Anderson
John B. Lucke, Bradford, Pa.
F. E. Eckert, W. T. Thom, Jr., John R. Sandidge
Lloyd E. Marsden, Bartlesville, Okla.
C. Maynard Boos, Max A. Pishel, Harry F. Wright
John A. Murphy, Tulsa, Okla.
C. L. Severy, L. L. Hutchison, Phil B. Dolman
Joseph L. Myers, Tulsa, Okla.
J. B. Leiser, L. G. Christie, A. I. Levorsen
Hugh T. Richardson, Alpine, Tex.
T. J. Galbraith, P. A. Grant, Fred S. Wright
Lon B. Turk, Tulsa, Okla.
C. G. Carlson, Kent K. Kimball, George I. McFerron

FOR TRANSFER TO ACTIVE MEMBERSHIP

Henry Hemmings, Tampico, Mexico
W. L. F. Nuttall, A. C. Trowbridge, A. C. Tester
Paul D. Torrey, Bradford, Pa.
L. G. Huntley, Shirley L. Mason, R. E. Somers
Karl E. Young, Sulphur, La.
Marcus A. Hanna, Frank W. DeWolf, W. C. Spooner

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## EXECUTIVE COMMITTEE MEETING, TULSA, FEBRUARY 1, 1930

The executive committee met at Association headquarters, 504 Tulsa Building, Tulsa, Oklahoma, February 1, 1930, with four members present, namely, president J. Y. Snyder of Shreveport, Louisiana, past-president R. S. McFarland of Tulsa, Oklahoma, second vice-president A. R. Denison of Fort Worth, Texas, and third vice-president F. H. Lahee of Dallas, Texas. The committee received reports from the committees for the New Orleans meeting, March 20-22, 1930, and made further arrangements for the convention.

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## STORROW FELLOWSHIPS IN GEOLOGY AND GEOGRAPHY

Following the announcement by the chairman of the Division of Geology and Geography, of the National Research Council, of the funding by Mrs. J. J.

Storrow, of Boston, of several fellowships under that Division, the Committee on Fellowships makes the following announcement.

1. The fellowships are designed to aid young men of outstanding ability and genious for research to secure training and aid in entering research careers in geology or geography.

2. Candidates for these fellowships are presumed to have had the equivalent of the bachelor's degree, but will not be required to have the doctor's degree either in hand or in view. Some fellowships may be awarded to men of proved aptitude and other qualities, who are not now in college but who need further training in order to enter the research field.

3. The fellowships are without restriction as to university, though the committee reserves the right to determine the location. The stipend, with commitments for one year only, ranges from $1,200 upward, according to conditions obtaining in the particular case.

The sole stipulation imposed by the donor of the funds is that she may be given opportunity to establish acquaintance with the holders of the fellowships.

Applications giving full information as to training, experience, and plans, with mention of any fellowships or scholarships already held, should be in the hands of the chairman of the committee before April 5, 1930. They should be addressed to Chairman, Committee on Fellowships, Division of Geology and Geography, National Research Council, B and 21st Streets, Washington, D. C.

DAVID WHITE,
*Chairman of Committee*

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## DISTRICT REPRESENTATIVES AND THE BUSINESS COMMITTEE

Many inquiries have come to us regarding our districts and district representatives, with particular reference to the geographic boundaries of the districts, the number of representatives from each district, the number of active members within each district, and so on. Inasmuch as these groups are of fundamental importance to the membership, in that they, through their representatives, are the actuating machinery of the organization, we take the space, at this time of the annual meeting, to quote Sections 5 and 6 of our By-Laws, and to add a few words of explanation.

> *Section 5.* The Executive Committee shall from time to time designate and define districts, and shall determine, according to the number of active members residing in each such district, the number of representatives to which it is entitled, and the active members in each such district shall choose, in such manner as to them seems best, the number of representatives to which the district is entitled. The terms of all district representatives hereafter elected shall be two years, and shall expire at the same time as the terms of officers.
>
> *Section 6.* There shall be a business committee to act as a council and advisory board to the executive committee and the Association. This committee shall be made up of the executive committee, not more than five members at large appointed by the president, two members elected by and from each technical section, and the district representa-

tives. The president shall also appoint a chairman from within or without the number of those theretofore chosen for the committee. If a district or technical representative is unable to be present at any meeting of the committee he may designate an alternate, who in the case of a district representative, may or may not be a resident of the district he is asked to represent, and the alternate, on presentation of such a designation in writing, shall have the same powers and privileges as a regularly chosen representative.

The Association has 27 district representatives apportioned to geographic groups of members as indicated on the accompanying map of the United States. These representatives form a majority of the members composing the general business committee. The foregoing excerpts from the By-Laws show the full make-up of the business committee. Inasmuch as this committee sifts, and recommends to the Association, the business that should be considered at the annual meeting, it is seen that the district representatives hold responsible positions. Prior to 1927 the executive committee was assisted in carrying on the business of the Association by a business committee whose members were appointed annually by the president. In March, 1927, the Association provided for the *election* of business committee members by the local active (full) Association members whom they were to represent. The executive committee was charged with defining geographic districts and determining the number of representatives for each district. This was accordingly accomplished in May, 1927, by the designation of 17 districts in the United States and 3 foreign districts, namely, Canada, Mexico, and South America. One representative was allowed for approximately every 50 active members. Due consideration, however, was given small local groups that were already organized as geolog-

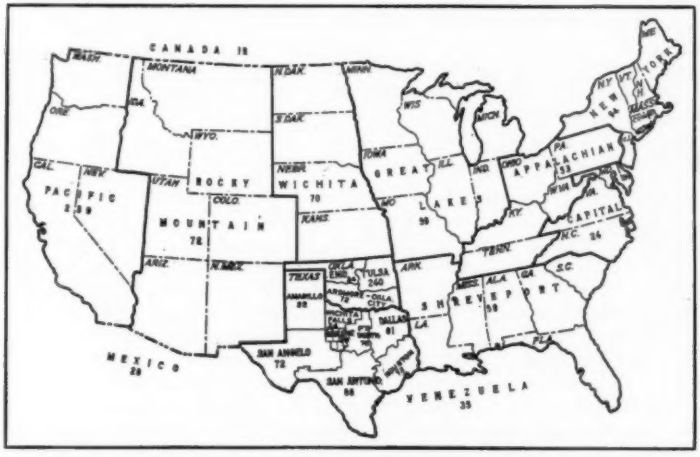


FIG. 1—Map showing number of active (full) members in A. A. P. G. districts.

ical societies and were active in Association affairs. Within a year, two additional districts were named, Abilene and San Antonio, as shown in Figure 1, so that the active (voting) members of the A. A. P. G. are now grouped into 19 districts in the United States and 3 outside, and are especially represented in Association affairs by 27 elected district representatives out of a possible total of 37 members of the general business committee which has a chairman appointed by the president of the Association.

Districts should not be confused with regional sections. Districts are geographic units designated as workable means of giving the voting members satisfactory representation. Regional sections (Art. 8 of the Constitution) are organized geological societies officially chartered by the A. A. P. G. for mutual benefit and close coöperation in attaining the objects of the Association as set forth in the Constitution.

The current list of district representatives is printed on the page preceding the Table of Contents of each *Bulletin*.

F. H. LAHEE

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## REVOLVING PUBLICATION FUND

The Fort Worth Geological Society has donated $900.00 to the A. A. P. G. Revolving Publication Fund. This is the first donation to the fund since it was established by a gift of $4,114.84 from the New York local committee on arrangements for the fall meeting of the Association in New York City, November, 1926. The purpose of this fund is to defray the expense of special publications of the Association, that is, of publications other than the regular monthly *Bulletin*. *Theory of Continental Drift* (1928) and *Structure of Typical American Oil Fields*, Volume I (1929), have been financed wholly by the fund, and *Structure of Typical American Oil Fields*, Volume II (1929), by the fund with the assistance of the Association's general fund.

## FINANCIAL STATEMENT, 1929

WILLSON & GARNETT, CERTIFIED PUBLIC ACCOUNTANTS
Kennedy Building, Tulsa, Oklahoma, January 28, 1930.

MR. A. R. DENISON, Vice-President in Charge of Finances,
American Association of Petroleum Geologists, Tulsa, Oklahoma.

DEAR SIR:

At your request we have examined the books and records of the American Association of Petroleum Geologists, Tulsa, Oklahoma, for the year ending December 31, 1929, and submit herewith the following statements.

Exhibit A—Balance Sheet, as at December 31, 1929
Schedule A-1—Inventory Printed Matter on hand at December 31, 1929
Schedule A-2—Investments, as at December 31, 1929
Exhibit B—Statement of Income and Expenses for the year 1929
Schedule B-1—Cost of Printed Matter Sold, 1929 (General Fund)
Exhibit C—Comparative Statement of Income and Expenses, General Fund, 1928 and 1929

*Scope of examination.*—We checked all disbursements with cancelled checks, ascertained that all receipts were duly deposited in the bank, and reconciled the Association's bank accounts by means of certificates obtained from the depositories. The inventory of printed matter on hand was taken by our representative, its value being based upon actual cost of printing. Except as hereinafter stated, the Association's investments are in the custody of the Exchange National Company, Tulsa, Oklahoma, from whom we obtained a certificate to that effect. The proceeds of the sale of two Life Memberships, $600.00, have been invested in Morris Plan Investment Certificates, bearing interest at 6 per cent per annum. We inspected these certificates at the Association's safe deposit vault at the National Bank of Commerce, Tulsa, Oklahoma. The balance of $403.86 remaining in the Research Fund is represented by a Savings Account with the Morris Plan Company of Oklahoma, Tulsa, Oklahoma.

We examined the membership records of the Association, and found dues unpaid at December 31, 1929, in the following amounts.

| | *1928* | *1929* | *Total* |
|---|---|---|---|
| Associate Dues | $10.00 | $390.00 | $400.00 |
| Active Dues | 10.00 | 820.00 | 830.00 |
| | $20.00 | $1,210.00 | $1,230.00 |

At January 27, 1930, there were still outstanding

| | |
|---|---|
| 1928 and 1929 Associate Dues | $380.00 |
| 1928 and 1929 Active Dues | 755.00 |
| | $1,135.00 |

A letter has been mailed to each delinquent member in an effort to collect these outstanding dues.

*Income and expenses.*—The operations of the Association are set forth in some detail on Exhibit B, which is supported by Schedule B-1, showing the cost of printed matter sold. The increase in this item is largely responsible for the decrease in the net operating income for the year 1929 as compared with that of the year 1928. We have prepared, and attach hereto as Exhibit C, a comparison of the operations affecting the General Fund for the years 1928 and 1929.

*General statement.*—We have verified sufficient of the detail of the books and records to be convinced of their clerical accuracy. They were found to be in excellent condition.

Should further information be desired with respect to the work done by us, or the statement submitted, we shall be pleased to furnish it upon request.

Respectfully submitted,

(Signed) WILLSON & GARNETT,
*Certified Public Accountants*

## EXHIBIT A

## BALANCE SHEET—DECEMBER 31, 1929

### ASSETS

| | *General Fund* | *Publication Fund* | *Research Fund* | *Total* |
|---|---|---|---|---|
| **CURRENT ASSETS** | | | | |
| Cash in Banks | $5,903.45 | $3,458.01 | | $9,361.46 |
| Notes Receivable | 15.00 | | | 15.00 |
| Accounts Receivable—Membership Dues | 1,230.00 | | | 1,230.00 |
| Other Accounts Receivable | 933.52 | 66.34 | | 999.86 |
| Interest Receivable | 444.33 | | | 444.33 |
| Inventory of Printed Matter | 14,711.97 | 2,281.16 | | 16,993.13 |
| Cost of Symposium, Vol. II, in Progress | | 1,849.33 | | 1,849.33 |
| | $23,238.27 | $7,654.84 | | $30,893.11 |
| **INVESTMENTS** | | | | |
| Bonds and Savings Certificates (Schedule A-2) | $28,199.45 | | $403.86 | $28,603.31 |
| **FIXED ASSETS** | | | | |
| Furniture and Fixtures, at depreciated value | $2,156.67 | | | $2,156.67 |
| **PREPAID EXPENSES** | | | | |
| Insurance Premiums paid in advance | $ 104.51 | | | $ 104.51 |
| *Total Assets* | $53,698.90 | $7,654.84 | $403.86 | $61,757.60 |

### LIABILITIES

| | *General Fund* | *Publication Fund* | *Research Fund* | *Total* |
|---|---|---|---|---|
| **CURRENT LIABILITIES** | | | | |
| Accounts Payable | $ 2,097.95 | $204.61 | | $ 2,302.56 |
| **DEFERRED INCOME** | | | | |
| Dues, Subscriptions and Sundry Income Applicable to 1930 | $ 4,913.47 | $ 2,450.72 | | $ 7,364.19 |
| **SURPLUS** | | | | |
| As at January 1, 1929 | $39,569.11 | $ 3,240.68 | | $42,809.79 |
| Adjustments to 1928 | 282.00 | | | 282.00 |
| | $39,851.11 | $ 3,240.68 | | $43,091.79 |
| Net Income, Year 1929 (Exhibit B) | 6,836.37 | 1,758.83 | $403.86 | 8,999.06 |
| | $46,687.48 | $4,999.51 | $403.86 | $52,090.85 |
| *Total Liabilities* | $53,698.90 | $ 7,654.84 | $403.86 | $61,757.60 |

SCHEDULE A-1

INVENTORY—DECEMBER 31, 1929

GENERAL FUND

| BULLETIN (PAPER COVERS) | | *Dec. 31, 1929 On Hand* | *Printing Cost* | *Cost* | |
|---|---|---|---|---|---|
| Vol. 2 | | 166 | $1.15 | $190.90 | |
| Vol. 3 | | 92 | 1.80 | 165.60 | |
| Vol. 4 | No. 2 | 38 | 1.13 | 42.94 | |
| | No. 3 | 48 | 1.13 | 54.24 | |
| Vol. 5 | No. 1 | ... | .... | .... | |
| | No. 2 | 117 | .90 | 105.30 | |
| | No. 3 | 193 | .37 | 71.41 | |
| | No. 4 | 204 | .30 | 61.20 | |
| | No. 5 | 163 | .40 | 65.20 | |
| | No. 6 | 53 | .32 | 16.96 | |
| Vol. 6 | No. 1 | 6 | .29 | 1.74 | |
| | No. 2 | 89 | .39 | 34.71 | |
| | No. 3 | 191 | .40 | 76.40 | |
| | No. 4 | 179 | .37 | 66.23 | |
| | No. 5 | 231 | .35 | 80.85 | |
| | No. 6 | 220 | .29 | 63.80 | |
| Vol. 7 | No. 1 | 186 | .61 | 113.46 | |
| | No. 2 | 76 | .60 | 45.60 | |
| | No. 3 | 40 | .55 | 22.00 | |
| | No. 4 | 114 | .66 | 75.24 | |
| | No. 5 | 107 | .63 | 67.41 | |
| | No. 6 | 59 | .64 | 37.76 | |
| Vol. 8 | No. 1 | 240 | .68 | 163.20 | |
| | No. 2 | ... | .... | .... | |
| | No. 3 | 144 | .79 | 113.76 | |
| | No. 4 | 179 | .65 | 116.35 | |
| | No. 5 | 291 | .69 | 200.79 | |
| | No. 6 | 226 | .89 | 201.14 | |
| Vol. 9 | No. 1 | 69 | .82 | 56.58 | |
| | No. 2 | 65 | 1.38 | 89.70 | |
| | No. 3 | 71 | 1.27 | 90.17 | |
| | No. 4 | 121 | .49 | 59.29 | |
| | No. 5 | 78 | .39 | 30.42 | |
| | No. 6 | 92 | .49 | 45.08 | |
| | No. 7 | 128 | .42 | 53.76 | |
| | No. 8 | 94 | .56 | 52.64 | |
| | No. 9 | 148 | .44 | 65.12 | |
| Vol. 10 | No. 1 | 106 | .39 | 41.34 | |
| | No. 2 | 22 | .49 | 10.78 | |
| | No. 3 | 105 | .64 | 67.20 | |
| | No. 4 | 150 | .38 | 57.00 | |
| | No. 5 | 154 | .34 | 52.36 | |
| | No. 6 | 184 | .39 | 71.76 | |
| | No. 7 | 204 | .35 | 71.40 | |
| | No. 8 | 158 | .28 | 44.24 | |
| | No. 9 | 223 | .35 | 78.05 | |
| | No. 10 | 165 | .38 | 62.70 | |
| | No. 11 | 108 | .54 | 58.32 | |
| | No. 12 | 133 | .58 | 77.14 | |
| *Forward* | | | | | $3,489.24 |

GENERAL FUND—*Continued*

| | | | | | |
|---|---|---|---|---|---|
| *Forwarded* | | | | | $3,489.24 |
| Vol. 11 | No. 1 | ... | .... | .... | |
| | No. 2 | ... | .... | .... | |
| | No. 3 | 1 | .47 | .47 | |
| | No. 4 | 14 | .32 | 4.48 | |
| | No. 5 | 27 | .39 | 10.53 | |
| | No. 6 | 93 | .37 | 34.41 | |
| | No. 7 | 1 | .44 | .44 | |
| | No. 8 | 51 | .44 | 22.44 | |
| | No. 9 | 31 | .45 | 13.95 | |
| | No. 10 | 45 | .34 | 15.30 | |
| | No. 11 | 72 | .37 | 26.64 | |
| | No. 12 | 27 | .50 | 13.50 | |
| Vol. 12 | No. 1 | 5 | .42 | 2.10 | |
| | No. 2 | ... | .... | .... | |
| | No. 3 | 16 | .43 | 6.88 | |
| | No. 4 | 25 | .41 | 10.25 | |
| | No. 5 | 26 | .48 | 7.68 | |
| | No. 6 | 28 | .36 | 10.08 | |
| | No. 7 | 69 | .39 | 26.91 | |
| | No. 8 | 65 | .36 | 23.40 | |
| | No. 9 | 114 | .35 | 39.90 | |
| | No. 10 | 81 | .35 | 28.35 | |
| | No. 11 | 90 | .35 | 30.50 | |
| | No. 12 | 66 | .35 | 23.10 | |
| Vol. 13 | No. 1 | 1,183 | .36 | 425.88 | |
| | No. 2 | 1,193 | .36 | 429.48 | |
| | No. 3 | 1,251 | .36 | 450.36 | |
| | No. 4 | 1,238 | .38 | 470.44 | |
| | No. 5 | 1,263 | .38 | 479.94 | |
| | No. 6 | 1,234 | .50 | 617.00 | |
| | No. 7 | 1,288 | .57 | 734.16 | |
| | No. 8 | 1,285 | .67 | 860.95 | |
| | No. 9 | 1,307 | .50 | 653.50 | |
| | No. 10 | 1,304 | .58 | 756.32 | |
| | No. 11 | 1,341 | .36 | 484.66 | |
| | No. 12 | 1,323 | .42 | 555.66 | |
| BULLETIN (BOUND) | | | | | |
| Vol. 5 | | 77 | 4.02 | 309.54 | |
| Vol. 6 | | 18 | 3.41 | 61.38 | |
| Vol. 7 | | 23 | 4.38 | 100.74 | |
| Vol. 8 | | 25 | 5.35 | 133.75 | |
| Sets 9 | | 32 | 3.99 | 127.68 | |
| Sets 10 | | 30½ | 3.59 | 108.60 | |
| Sets 11 | | 207 | 3.36 | 695.52 | |
| Sets 12 | | 229½ | 6.28 | 1,441.26 | |
| TOTAL INVENTORY, BULLETIN (PAPER COVERS AND CLOTH BOUND) | | | | | $13,736.97 |
| GEOLOGY OF SALT DOME OIL FIELDS | | ..... | .... | ..... | |
| INDEX I-X INCL. | | 1,950 | $.50 | 975.00 | 975.00 |
| TOTAL INVENTORY, GENERAL FUND | | | | | $14,711.97 |

PUBLICATION FUND

| | | | |
|---|---|---|---|
| CONTINENTAL DRIFT | 293 | $1.97 | $577.21 |
| STRUCTURE VOL. I | 95 | 3.97 | 377.15 |
| STRUCTURE VOL. I | 1,000 | 1.28 | 1,280.00 |
| STRUCTURE VOL. II | 13 | 3.60 | 46.80 |
| TOTAL INVENTORY, PUBLICATION FUND | | | $2,281.16 |

SCHEDULE A-2

INVESTMENTS—DECEMBER 31, 1929

| | *Interest Rate Per Cent* | *Par Value* | *Cost* |
|---|---|---|---|
| BONDS | | | |
| Allied Owners Corporation | 6 | $2,000.00 | $1,980.00 |
| Argentine Government External Loan | 6 | 1,000.00 | 997.50 |
| Exchange National Co. Part. Certificate | 5½ | 500.00 | 500.00 |
| Exchange Trust Co. R. E. Savings Bond | 5½ | 1,100.00 | 1,100.00 |
| Hardin County, Texas, Road Bond | 5 | 1,000.00 | 984.20 |
| Imperial Japanese Government | 6½ | 500.00 | 462.50 |
| Indiana Hydro-Electric Corporation | 5 | 3,000.00 | 2,910.00 |
| Nevada-California Electric Corporation | 5 | 3,000.00 | 2,865.00 |
| Northern State Power Company | 6 | 1,500.00 | 1,493.25 |
| Pondera County Montana Refunding | 5½ | 1,000.00 | 1,000.00 |
| Pure Oil Company | 5½ | 3,000.00 | 2,960.00 |
| U. S. Rubber Company | 5 | 1,000.00 | 859.50 |
| Public Service Co. of Oklahoma | 5 | 2,000.00 | 1,980.00 |
| Abitibi Light & Paper Company | 5 | 2,000.00 | 1,740.00 |
| Goodyear Tire & Rubber Company | 5 | 2,000.00 | 1,855.00 |
| Central Public Service Company | 5½ | 1,000.00 | 965.00 |
| Skelly Oil Company | 5½ | 1,000.00 | 931.25 |
| Sinclair Consolidated Oil Corp. | 6 | 1,000.00 | 998.75 |
| The Texas Corporation Convert. Deb. Bonds | 5 | 1,000.00 | 1,017.50 |
| TOTAL BONDS | | | $27,599.45 |
| MORRIS PLAN INVESTMENT CERTIFICATE (Life Membership Fund) | | | 600.00 |
| TOTAL INVESTMENTS | | | $28.199.45 |

EXHIBIT B

STATEMENT OF INCOME AND EXPENSES—YEAR 1929

| | *General Fund* | | *Publication Fund* | *Research Fund* | *Total* |
|---|---|---|---|---|---|
| INCOME | | | | | |
| *Membership Dues* | | | | | |
| Associate | $ 6,848.00 | | | | |
| Active | 23,972.00 | | | | |
| Life | 600.00 | $31,420.00 | | | |
| *Bulletins* | | | | | |
| Subscriptions | 4,146.53 | | | | |
| Sale of Bound Copies | 3,605.20 | | | | |
| Sale of Indexes | 399.04 | | | | |
| Sale of Back Numbers and Separates | 858.40 | | | | |
| Sale of Salt Dome Vol. | 734.66 | | | | |
| Advertising | 6,973.95 | 16,717.78 | | | |
| *Other Publications* | | | | | |
| Sale of Continental Drift | | | $ 998.42 | | |
| Sale of Structure Vol. I | | | 5,271.71 | | |
| *Contributions, etc.* | | | | | |
| Research Fund | | | | $853.46 | |
| TOTAL INCOME FROM OPERATIONS | | $48,137.78 | $6,270.13 | $853.46 | $55,261.37 |
| EXPENSES | | | | | |
| *Cost of Printed Matter Sold* | | | | | |
| Cost of Printing | $22,061.25 | | | | |
| Editorial Secretary | 3,254.39 | | | | |
| | $25,315.64 | | | | |
| Stencil Corrections and Mailing | 447.92 | | | | |
| Miscellaneous | 97.30 | $25,860.86 | | | |
| Expenses Cont. Drift and Structure Vol. I | | | $ 4,603.67 | | |
| Expenses Research Committee | | | | 449.60 | 30,914.13 |
| GROSS PROFIT | | $22,276.92 | $1,666.46 | $403.86 | $24,347.24 |

EXHIBIT B—*Continued*

| | | | | | |
|---|---|---|---|---|---|
| GENERAL AND OFFICE EXPENSES | | | | | |
| Salary Business Manager | $ 7,500.00 | | | | |
| Salaries Clerical | 3,979.31 | | | | |
| Postage, Telephone and Telegraph | 1,613.43 | | | | |
| Stationery, Office Supplies and Expense | 1,294.07 | | | | |
| Executive, Traveling and Convention Expense | 792.93 | | | | |
| Audit Expense | 491.50 | | | | |
| Insurance and Taxes | 267.21 | | | | |
| Depreciation | 244.01 | | | | |
| Miscellaneous Expense | 248.50 | | | | |
| Contributions | 1,050.00 | $17,480.96 | | | 17,480.96 |
| INCOME FROM OPERATIONS | | $4,795.96 | $1,666.46 | $403.86 | $6,866.28 |
| OTHER INCOME | | | | | |
| Interest and Profit on Investments | | 1,919.36 | 74.27 | | 1,993.63 |
| Sundry Income | | 121.05 | 18.10 | | 139.15 |
| NET INCOME FOR THE YEAR 1929 | | $6,836.37 | $1,758.83 | $403.86 | $8,999.06 |

SCHEDULE B-I

COST OF PRINTED MATTER SOLD

GENERAL FUND

| | | | | |
|---|---|---|---|---|
| INVENTORY JANUARY 1, 1929 | | | | $11,601.35 |
| COST OF PRINTING, 1929 | | | | |
| Vol. 13 | No. 1 | $ 1,407.38 | | |
| | No. 2 | 1,387.05 | | |
| | No. 3 | 1,413.15 | | |
| | No. 4 | 1,465.25 | | |
| | No. 5 | 1,881.00 | | |
| | No. 6 | 1,958.00 | | |
| | No. 7 | 2,220.65 | | |
| | No. 8 | 2,621.95 | | |
| | No. 9 | 1,932.85 | | |
| | No. 10 | 2,269.25 | | |
| | No. 11 | 1,413.10 | | |
| | No. 12 | 1,646.00 | | |
| | CLOTH BINDING | 1,240.00 | | |
| | ENGRAVING | 1,706.70 | | |
| | PAPER BINDING | 70.00 | | |
| | SEPARATES | 539.54 | | 25,171.87 |
| | | | | $36,773.22 |
| Inventory, December 31, 1929 | | | | 14,711.97 |
| COST OF PRINTED MATTER SOLD, GENERAL FUND | | | | $22,061.25 |

EXHIBIT C

COMPARATIVE STATEMENT OF INCOME AND EXPENSES

GENERAL FUND

| | *1928* | *1929* | *Increase or Decrease* |
|---|---|---|---|
| INCOME | | | |
| Associate Membership Dues | $ 7,044.00 | $ 6,848.00 | $ −196.00 |
| Active Membership Dues | 20,171.10 | 23,972.00 | 3,800.90 |
| Life Membership Sold | | 600.00 | 600.00 |
| TOTAL MEMBERSHIPS | $27,215.10 | $31,420.00 | $ 4,204.90 |
| *Bulletins* | | | |
| Subscriptions | $4,130.04 | $4,146.53 | $ 16.49 |
| Sale of Bound Copies | 3,916.58 | 3,605.20 | −311.38 |
| Sale of Indexes | 236.90 | 399.04 | 162.14 |
| Sale of Back Numbers | 1,379.87 | 858.40 | −521.47 |
| Sale of Salt Dome Volumes | 791.46 | 734.66 | −56.80 |
| Advertising | 3,994.74 | 6,973.95 | 2,979.21 |
| TOTAL INCOME FROM BULLETINS | $14,449.59 | $16,717.78 | $2,268.19 |
| TOTAL INCOME FROM OPERATIONS | $41,664.69 | $48,137.78 | $6,473.09 |
| EXPENSES | | | |
| *Cost of Printed Matter Sold* | | | |
| Cost of Printing | $14,069.95 | $22,061.25 | $7,991.30 |
| Editorial Secretary | 2,896.15 | 3,254.39 | 358.24 |
| Stencil Corrections and Mailing | 635.70 | 447.92 | −187.78 |
| Miscellaneous | 386.68 | 97.30 | −289.38 |
| TOTAL COST OF PRINTED MATTER SOLD | $17,988.48 | $25,860.86 | $7,872.38 |
| GROSS INCOME | $23,676.21 | $22,276.92 | −1,399.29 |
| GENERAL AND OFFICE EXPENSES | | | |
| Salary Business Manager | $ 7,500.00 | $ 7,500.00 | |
| Salaries, Clerical | 3,417.50 | 3,979.31 | $ 561.81 |
| Telephone, Telegraph, and Postage | 1,440.44 | 1,613.43 | 172.99 |
| Printing, Stationery, and Supplies | 1,282.98 | 1,294.07 | 11.09 |
| Traveling and Convention Expenses | 615.86 | 792.93 | 177.07 |
| Insurance and Taxes | 122.03 | 267.21 | 145.18 |
| Depreciation | 169.83 | 244.01 | 74.18 |
| Donations | 1,050.00 | 1,050.00 | |
| Sundry | 414.54 | 248.50 | −166.04 |
| Auditing | | 491.50 | 491.50 |
| TOTAL GENERAL AND OFFICE EXPENSES | $16,013.18 | $17,480.96 | $1,467.78 |
| PROFIT FROM OPERATIONS | $7,663.03 | $4,795.96 | −2,867.07 |
| INTEREST ON INVESTMENTS AND SUNDRY | $2,494.47 | $2,040.41 | −454.06 |
| NET INCOME, YEAR 1929 | $10,157.50 | $6,836.37 | −3,321.13 |

# AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
# MEMBERSHIP LIST

## March 1, 1930

### HONORARY MEMBERS

The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary member shall not be required to pay dues, nor shall they be allowed to vote.—*Sec. 7, Article III of the Constitution.*

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### LIFE MEMBERS

The executive committee may grant life membership to active members who have paid their dues and are otherwise qualified.—*Sec. 1, Article III, of the Constitution.*

The fee required for life membership shall be $300 payable in advance.—*Sec. 1, of the By-Laws.*

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### ACTIVE MEMBERS

Any person actively engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership in the American Association of Petroleum Geologists, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, and in addition has had the equivalent of three years' field experience in petroleum geology; and provided further that in case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude instructors and professors in recognized institutions of learning whose work is of such a character as in the opinion of the executive committee shall qualfy them for membership. —*Sec. 1, Article III, of the Constitution.*

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### ASSOCIATE MEMBERS

Any person having completed as much as thirty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalen to this, shall be eligible to associate membership in the American Association of Petroleum Geologists provided that at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in geological work *Sec. 2.*

Associate members shall enjoy all privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote in business meetings; neither shall they have the privilege of advertising their associate membership in the Association in professional cards, nor shall they have the privilege of signing professional reports as associate members of the Association.—*Sec. 4, Article III, of the Constitution.*

||Abbott, John L., Texas Pacific Coal & Oil Co., Box 511, Carlsbad, N. M. '27
||Abell, George T., Midland Tex. '29
Abrahamson, Hjalmar, Texas Hotel, Fort Worth, Tex. '18
Abramovich, Michael, 2 Maligin St., Baku, U. S. S. R. '29
Abruns, Harry W., 1018 Board of Trade Bldg., Los Angeles, Calif. '27
||Absher, Kenneth B., Box 946, Eldorado, Kan. '25
Absher, William F., Empire Gas & Fuel Co., Geological Dept., Bartlesville, Okla. '20
Ackers, A. L., Southern Crude Oil Purchasing Co., Box 128, Midland, Tex. '25
Adams, Frank C., The Texas Company, Houston, Tex. '27
Adams, George I., University of Alabama, Tuscaloosa, Ala. '21
Adams, G. Whitney, 1400 Cottage St., Brownwood, Tex. '22
Adams, H. H., 415 W. T. Waggoner Bldg., Fort Worth, Tex. '19
Adams, John Emery, Box 1566, Midland, Tex. '29
||Adams, Theodore F., Radiore Co., 9035 Venice Blvd., Los Angeles, Calif. '29
Adams, W. C., Box 2203, Tulsa, Okla. '24
Adkins, W. S., Bureau of Economic Geology, University of Texas, Austin, Tex. '20
Aguerrevere, Pedro I., Sur 3, No. 94, Caracas, Venezuela, S. A. '24
Aguerrevere, Santiago E., Sur 3, No. 94, Caracas, Venezuela, S. A. '24
Aid, Herbert, Box 988, Wichita Falls, Tex. '28
Aimer, James D., Drawer 1731, Shreveport, La. '26
Ainsworth, David, 3240 E. Pine St., Wichita, Kan. '23
Ainsworth, William L., 301 N. Yale St., Wichita, Kan. '21
Albertson, Maurice M., Shell Petroleum Corp., Box 1672, Dallas, Tex. '20
||Alcalá, José G., Ave. Insurgentes 490, Mexico City, Mexico '29
Aldrich, G. Frank, 2024 Wilshire Blvd., Fort Worth, Tex. '25
||Aldridge, Mort B., Box 912, Tulsa, Okla. '27
||Alexander, C. I., Texas Christian University, Box 192, Fort Worth, Tex. '27
Allan, Thomas H., Box 362, Russell, Kan. '24
Allen, Bryant, Box 12, Laredo, Tex. '25
Allen, Devere F., Box 806, Roswell, N. M. '29
Allen, Donald M., c/o R. F. Allen, Vian, Okla. '24
Allen, E. G., Shell Petroleum Corp., Box 1672, Dallas, Tex. '17
Allen, Walter J., Box 2203, Tulsa, Okla. '18
Allison, A. P., Box 332, Brownwood, Tex. '21
Althaus, H. E., Leimenstrasse 72, Basel, Switzerland '28
Ambrose, A. W., Empire Gas & Fuel Co., Bartlesville, Okla. '19
Ames, Edward W., 910 Milam Bldg., San Antonio, Tex. '19
Ames, E. R., Texas Creosoting Co., Orange, Tex. '24
Anderson, Amil A., 721-722 Union Natl. Bank Bldg., Wichita, Kan. '22
Anderson, Carl B., 941 Kennedy Bldg., Tulsa, Okla. '19
Anderson, Frank M., 58 Hillcrest Road, Berkeley, Calif. '24
Anderson, G. E., 645 Lahoma, Norman, Okla. '24
||Anderson, Homer L., R. 2, Box 6, Lou Ann, Ark. '27
Anderson, J. G., Jr., Lumbermen's Club, Houston, Tex. '21
Anderson, J. L., Lago Petroleum Corp., Apartado 172, Maracaibo, Venezuela, S. A. '29
Anderson, Lyman P., Box 433, San Angelo, Tex. '27
Anderson, Robert V. V., c/o American Consul, Algiers, Algeria '23
||Anderson, Warren D., Box 832, San Angelo, Tex. '27
Andreen, Harry M., Box 2045, Tulsa, Okla. '27
Andrews, Philip, Barcelona, Venezuela, S. A. '25
Andrews, Sylvan H., 609 Exchange Bank Bldg., Tulsa, Okla. '20
Apfel, Earl T., Geological Dept., Syracuse University, Syracuse, N. Y. '29
Applin, Paul L., 1700 Electric Bldg., Fort Worth, Tex. '19
Argabrite, William Graeme, Room 1560, 26 Broadway, New York, N. Y. '28
||Arick, Millard B., Box 983, McCamey, Tex. '27
Armstrong, Harold K., Room 838, 727 W. Seventh St., Los Angeles, Calif. '27

*Honorary member. †Life member. ||Associate member. Active members are not marked. The year refers to date of election to the Association, not necessarily to class of membership.

Armstrong, J. M., Prairie Oil & Gas Co., Eastland, Tex. . . . '18
Arnett, Clarence L., 301 S. Eighth St., Ponca City, Okla. . . . '27
Arnold, Emmett L., 538 Mayo Bldg., Tulsa, Okla. . . . '27
||Arnold, Harry H., Jr., 749 E. Liberty St., Clarion, Pa. . . . '27
Arnold, Ralph, Subway Terminal Bldg., Los Angeles, Calif. . . . '18
Aronson, Sam M., 701 Magnolia Bldg., Dallas, Tex. . . . '24
Artman, George W., Box 1651, Amarillo, Tex. . . . '25
Athy, Lawrence F., Continental Oil Co., Ponca City, Okla. . . . '26
Atkinson, William H., 701 Continental Bldg., Oklahoma City, Okla. . . . '22
Aurand, Harry A., 1350 Bellaire St., Denver, Colo. . . . '26
Aurin, Fritz L., Southland Royalty Co., Ponca City, Okla. . . . '17
Autry, Vernon E., Humble Oil & Refining Co., Box 1034, Wichita Falls, Tex. . . . '26
Avery, C. Dwight, U. S. Geological Survey, 3240 Interior Bldg., Washington, D. C. . . '28

Bace, A. C., 803 San Angelo Natl. Bank Bldg., San Angelo, Tex. . . . '24
||Bacon, Charles S., Jr., Geology Dept., Riverside Junior College, Riverside, Calif. . '29
Baden, Martin W., Box 520, 201-202 Baden Bldg., Winfield, Kan. . . . '21
Bagg, Rufus M., 16 Brokaw Place, Appleton, Wis. . . . '27
Bailey, Thomas L., Box 713, Ventura, Calif. . . . '24
Bain, H. Foster, 29 W. Thirty-Ninth St., New York, N. Y. . . . '26
Baird, Chester A., Apartado 234, Venezuela Gulf Oil Co., Maracaibo, Venezuela, S. A. . . . '21
Baker, Arthur A., U. S. Geological Survey, Washington, D. C. . . . '30
Baker, Charles L., 529 Commercial Bank Bldg., Houston, Tex. . . . '19
||Baker, Lara H., 433 S. Broadway, Tyler, Tex. . . . '29
Baker, Norval E., Room 1567, 26 Broadway, New York, N. Y. . . . '27
Baker, Raymond F., The Texas Co., Geological Dept., 17 Battery Place, New York, N. Y. . . . '17
Baker, William A., Jr., Apartado 657, Tampico, Mexico . . . '24
||Bakke, W. E., Shell Petroleum Corp., Box 1555, Oklahoma City, Okla. . . . '28
Baldwin, E. B., Box 322, Victoria, Tex. . . . '29
Baldwin, H. L., 224 E. Thirteenth St., Oklahoma City, Okla. . . . '21
Baldwin, Harry L., Jr., 600 W. Twentieth St., Oklahoma City, Okla. . . . '22
Bale, Hubert E., 1130 W. Forty-First St., Oklahoma City, Okla. . . . '24
Ball, Max W., 715 First Natl. Bank Bldg., Denver, Colo. . . . '19
Ball, Sydney H., 26 Beaver St., New York, N. Y. . . . '19
||Ballard, Andrew L., 703 Travis Bldg., San Antonio, Tex. . . . '21
||Ballard, James L., 515 S. Bois d'Arc, Tyler, Tex. . . . '25
||Ballard, William Norval, 1201 First Natl. Bank Bldg., Oklahoma City, Okla. . . . '29
Banks, Thomas R., 715 Park Ave., Corpus Christi, Tex. . . . '27
||Barbat, William F., Standard Oil Co., Taft, Calif. . . . '28
Bard, Richards J., Wayne, Pa. . . . '28
||Barling, Robert, Midland, Tex. . . . '27
||Barlow, Victor, 121 N. Hill St., Los Angeles, Calif. . . . '27
Barnes, Roy M., Continental Oil Co., 417 S. Hill St., Los Angeles, Calif. . . . '24
Barnett, D. G., 1007 Electric Bldg., Fort Worth, Tex. . . . '25
||Barnett, J. A., Box 112, Big Spring, Tex. . . . '28
||Barnhart, Carl F., Box 2044, Tulsa, Okla. . . . '29
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Goodrich, Raymond H., 2117 Gulf Bldg., Houston, Tex. '24
Goodrich, Robert D., 706 Fort Worth Natl. Bank Bldg., Fort Worth, Tex. '18
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Hagy, Lawrence R., 508 Amarillo Bldg., Amarillo, Tex.....'25
||Hahn, Raymond R., Barnes, Warren Co., Pa.....'23
||Haight, Harold W., Transcontinental Petr. Co., Apartado 657, Tampico, Mexico '27
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Hall, Ellis A., Box 211, Abilene, Tex.....'25
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Hancock, Eugene T., Romano-Americana, Ploesti, Roumania.....'28
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Hanna, Marcus A., 2910 Arbor, Houston, Tex.....'25
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Taylor, Dewitt E., 409 Haberfelde Bldg., Bakersfield, Calif. '28
||Taylor, Russell W., Box 558, Wichita, Kan. '29
Taylor, Thomas G., Box 4029, Shawnee, Okla. '25
Teas, L. P., Humble Oil & Refg. Co., Houston, Tex. '21
Teas, Paul C., Box 507, Colorado, Tex. '22
||Teddlie, John F., Jr., Box 368, Olney, Tex. '28
Templeton, E. C., Union Natl. Petroleum Co., Apartado 484, Caracas, Venezuela, S. A. '27
Templeton, James B., Box 727, Tyler, Tex. '25
Templeton, James Clark, British Controlled Oilfields, Apartado 232, Maracaibo, Venezuela, S. A. '26
Terrill, J. V., Box 1428, Amarillo, Tex. '28
Tester, Allen C., Dept. of Geology, University of Iowa, Iowa City, Iowa '21
Thalmann, Hans E., "El Aguila," S. A., Apartado 86, Puerto Mexico, Ver., Mexico '27
Thom, W. T., Jr., Dept. of Geology, Princeton University, Princeton, N. J. '22
Thomas, C. R., 3816 E. Lewis, Wichita, Kan. '20
Thomas, Elmslie T., Address Unknown '23
Thomas, George Dewey, 4961 Laclede, Apt. 407, St. Louis, Mo. '27
Thomas, G. Gordon, "Ridgeways," Minchinhampton, Gloucestershire, England. '26
Thomas, J. Elmer, 602 Fort Worth Club Bldg., Fort Worth, Tex. '17
Thomas, Norman L., Pure Oil Co., Box 1007, Fort Worth, Tex. '26
Thomas, William A., Pure Oil Co., 402 Second Natl. Bank Bldg., Saginaw, Mich. '26
Thompson, A. Beeby, 18 St. Swithins Lane, London, E. C. 4, England '19
Thompson, B. E., Gulf Production Co., Box 737, Fort Worth, Tex. '24
Thompson, Charles L., Box 997, Eastland, Tex. '28
Thompson, Evan G., Drawer C, Houston, Tex. '29
Thompson, James D., Jr., Room 3, Amarillo Natl. Bank Bldg., Amarillo, Tex. '23
Thompson, R. R., 307 Petroleum Bldg., Fort Worth, Tex. '20
||Thompson, Raymon H., U. S. Veteran's Hospital No. 93, Legion, Tex. '27
Thompson, Sheridan A., Vacuum Oil Co., Box 1426, Houston, Tex. '23
Thompson, T. C., Box 84, Vernon, Tex. '22
Thompson, Wallace C., Box 807, Tyler, Tex. '20
||Thompson, Warren O., Dept. of Geology, University of Colorado, Boulder, Colo. '27
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Thomson, H. Britton, Pure Oil Co., Petroleum Bldg., Fort Worth, Tex. '23
Thornburg, D. H., 522 W. Highland, San Angelo, Tex. '23
Thornburgh, H. R., 4016 Rawlins, Dallas, Tex. '25
Tickell, Frederick F., 652 Forest Ave., Palo Alto, Calif. '23
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Tieje, Arthur J., 2016 S. La Salle Ave., Los Angeles, Calif. '25

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||Tillotson, Allen W., Box 130, Parco, Wyo. ..... '28
Tillotson, Harold H., Latham, Kan. ..... '24
Tims, Virgil E., Box 1555, Oklahoma City, Okla. ..... '27
||Toler, Henry N., Box 673, Meridian, Miss. ..... '26
||Tollefson, E. H., Manufacturer's Light & Heat Co., Union Trust Bldg., Pittsburgh, Pa. ..... '26
Tolmachoff, I. P., Carnegie Museum, Pittsburgh, Pa. ..... '27
Tomlinson, Charles W., 610 Simpson Bldg., Ardmore, Okla. ..... '21
||Tompkins, J. D., 512 S. Dixie St., Eastland, Tex. ..... '29
Tong, James A., Geological Dept., Johns Hopkins University, Baltimore, Md. ..... '25
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Tschopp, H. J., Cia. Mex. "El Aguila," S. A., Puerto Mexico, Ver., Mexico ..... '27
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Van Couvering, Martin, 841 Petroleum Securities Bldg., 714 W. Tenth St., Los Angeles, Calif. ..... '24
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van der Gracht, W. A. J. M., Schloss Hainfeld, Feldbach, Steiermark, Austria ..... '17

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||Vanderpool, Harold C., Rycade Oil Corp., Box D, Eagle Pass, Tex. . . . . '26
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||Walters, Mason G., Room 25, Y. M. C. A., Bradford, Pa. . . . . '28

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Wanemacher, Joseph M., Room 717, 21 State St., New York, N. Y....'27
Waring, Gerald A., Margay Oil Corp., Box 2103, Tulsa, Okla....'23
Waring, W. W., 45 Rosenwald Hall, University of Chicago, Chicago, Ill....'29
Warner, Charles A., 718 World Bldg., Tulsa, Okla....'19
Warner, Julius H., 1016 First Natl. Bank Bldg., Denver, Colo....'20
||Warren, Howard C., Geological Dept., Empire Companies, Bartlesville, Okla....'28
Warren, Van Court, 812 Subway Terminal Bldg., Los Angeles, Calif....'23
||Warthin, Aldred S., Jr., Geological Dept., Vassar College, Poughkeepsie, N. Y....'28
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Wasson, Isabel B., 138 Keystone Ave., River Forest, Ill....'27
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Waterfall, Louis N., Union Oil Co. of California, Union Oil Bldg., Los Angeles, Calif....'24
Waters, James A., Sun Oil Co., Box 953, Dallas, Tex....'25
Watkins, William A., Edificio Banco Boston 713, Buenos Aires, Argentina, S. A....'23
Watson, C. P., 1809 Electric Bldg. Fort Worth, Tex....'25
Watson, Joseph D., 1135 Hunt Bldg., Tulsa, Okla....'21
||Watson, W. Verde, Midwest Refining Co., Box 681, Roswell, N. M....'27
||Weaver, Donald K., 446 N. Commercial Ave., Whittier, Calif....'25
Weaver, George A., Pure Oil Co., Box 1007, Fort Worth, Tex....'26
Weaver, Paul, Drawer C, Houston, Tex....'20
Webb, John B., 407 Herald Bldg., Calgary, Alta., Canada....'29
Webster, Hugh B., Standard Oil Co., San Francisco, Calif....'21
||Weddle, Herman W., 225 Bush St., San Francisco, Calif....'29
||Weed, William F., 325 Seventh St., Beaumont, Tex....'26
Weeks, Albert W., 1118 City Natl. Bank Bldg., San Antonio, Tex....'27
||Weeks, Herbert J., Sun Oil Co., 1608 Walnut St., Philadelphia, Pa....'24
Weeks, Lewis G., Edificio Banco Boston, Avenida Roque Saenz Peña 567, Buenos Aires, Argentina, S. A....'24
||Weeks, Warren B., 649 E. Park, Oklahoma City, Okla....'29
Wegemann, Carroll H., Pan-American Petr. & Trans. Co., 122 E. Forty-Second St., New York, N. Y....'20
||Weintz, Clement A., Midwest Refining Co., Casper, Wyo....'27
Weinzierl, John F., 607-8 Petroleum Bldg., Houston, Tex....'22
Weirich, T. E., Tidal Oil Co., Tulsa, Okla....'21
Weisbord, Norman E., Apartado 223, Maracaibo, Venezuela, S. A....'25
||Welch, Virgil H., 208 W. Wallace, Shawnee, Okla....'27
||Weller, J. Marvin, State Geological Survey, Urbana, Ill....'29
Wellings, F. E., Iraq Petroleum Corp., King William St. House, London, E. C. 4, England....'24
Wells, Lloyd E., 806 Eighth St., Wichita Falls, Tex....'23
Wells, Samuel W., Box 1266, Okmulgee, Okla....'19
Welsh, LeRoy G., Blackstone Hotel, Fort Worth, Tex....'19
Wender, W. G., Box 1058, Cisco, Tex....'26
Wendlandt, E. A., Humble Oil & Rfg. Co., Box 598, Tyler, Tex....'24
West, Joe W., Purcell, Okla....'23
Westby, Gerald H., Empire Oil & Rfg. Co., Geological Dept., Bartlesville, Okla....'23
||Weymouth, A. Allen, Box 2410, Denver, Colo....'29
||Wharton, H. Jerome, Apartado 234, Maracaibo, Venezuela, S. A....'28
Whealton, Rowland G., 2116 Las Lunas St., Pasadena, Calif....'25
||Wheeler, Carlton W., Box 749, Ardmore, Okla....'20
||Wheeler, Girard E., 220 Traders Bldg., Calgary, Alta., Canada....'29
Wheeler, H. A., Security Bldg., St. Louis, Mo....'27

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||Wheeler, Holmes Cubbage, Box 507, Colorado, Tex.....'25
Wheeler, James D., Sun Oil Co., Box 807, Tyler, Tex.....'29
Wheeler, Orby Clinton, Tropical Oil Co., Cartagena, Colombia, S. A.....'26
||Wheless, Randolph F., Box 306, Seguin, Tex.....'29
Whisenant, John B., Box 307, Big Springs, Tex.....'25
Whitcomb, Bruce, 1700 Electric Bldg., Fort Worth, Tex.....'24
*White, David, U. S. Geological Survey, Washington, D. C.....'19
White, Edwin E., Box 595, Paintsville, Ky.....'19
||White, Gordon H., Shell Oil Co., Higgins Bldg., Los Angeles, Calif.....'29
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White, Luther H., 211 E. Jasper St., Tulsa, Okla.....'20
White, Maynard P., Gypsy Oil Co., Box 30, Ardmore, Okla.....'25
White, Roger F., Bank of America Bldg., Los Angeles, Calif.....'23
White, Stanley B., Box 2064, Tulsa, Okla.....'24
Whitehead, R. B., 702 Magnolia Bldg., Dallas, Tex.....'19
Whitehead, W. L., 222 Charles River Road, Cambridge, Mas.....'29
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Whitney, F. L., 4310 Avenue H, Austin, Tex.....'20
Whitney, Paul A., Mid-Continent Petroleum Corp., 612 Orpheum Bldg., Wichita, Kan.....'24
Whitney, Paul B., Geo. F. Getty, Inc., 1060 Subway Terminal Bldg., Los Angeles, Calif.....'23
Whittier, William H., Shell Oil Co., 403 Higgins Bldg., Los Angeles, Calif.....'24
Whitwell, E. V., General Delivery, Jackson, Miss.....'18
Whorton, Chester D., Box 151, Graham, Tex.....'29
Wiedenmayer, Carl, Creole Petroleum Corp., Apartado 85, Maracaibo, Venezuela, S. A.....'26
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Wilcox, Fred H., Independent Oil & Gas Co., San Angelo, Tex.....'29
||Wilhelm, Arthur K., 703 Empire Bldg., Bartlesville, Okla.....'28
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Williams, D. W., 3118 Newton St., N. E., Washington, D. C.....'18
||Williams, E. D., 131 W. Poplar, Oklahoma City, Okla.....'27
||Williams, Francis S., W. C. McBride, Inc., Box 117, McPherson, Kan.....'24
||Williams, G. Allen, 844 Kennedy Bldg., Tulsa, Okla.....'27
||Williams, George C., 302 W. Anapamu St., Santa Barbara, Calif.....'27
Williams, George O., 1319 E. Eighth St., Okmulgee, Okla.....'28
Williams, Herbert E., Vickers Petroleum Co., W. K. H. Bldg., Wichita, Kan.....'26
Williams, James S., 103 Geology Bldg., University of Missouri, Columbia, Mo.....'29
Williams, Thomas B., 515 Lougheed Bldg., Calgary, Alta., Canada.....'30
Williams, W. A., Crown Central Petroleum Co., Post Dispatch Bldg., Houston, Tex.....'19
||Williamson, Thomas S., 411 N. Fifth St., Henryetta, Okla.....'26
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Willis, Robin, Box 1405, Midland, Tex.....'27
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Williston, Samuel H., Sun Oil Co., Box 953, Dallas, Tex.....'24
Willson, Kenneth M., 1312 S. Quaker St., Tulsa, Okla.....'29
Wilshire, L. M., 1704 S. Evanston, Tulsa, Okla.....'23
Wilson, Edward B., Sun Oil Co., San Angelo, Tex.....'22
||Wilson, Homer M., Box 813, Del Rio, Tex.....'27
Wilson, John H., Box 187, Golden Colo.....'21
Wilson, Joseph M., Simms Oil Co., 10th Floor Magnolia Bldg., Dallas, Tex.....'22
Wilson, Leslie E., 1811 Thirteenth St., Bakersfield, Calif.....'26
Wilson, Malcolm E., 104 E. Grove St., El Dorado, Ark.....'20

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||Winterer, Edward V., 317 Haberfelde Bldg. Bakersfield, Calif.....'27
Winton, Will M., Texas Christian University, Fort Worth, Tex.....'20
Wissler, Stanley G., Dept. of Research & Development, Union Oil Co., Wilmington, Calif.....'27
Witt, Herbert N., 512 Sharon Bldg., San Francisco, Calif.....'21
Wolf, Albert G., Texas Gulf Sulphur Co., 1009 Second Natl. Bank Bldg., Houston, Tex.....'24
Wolff, Deane J., 404 Back Bay Blvd., Wichita, Kan.....'23
Wood, Fred E., Midwest Refining Co., Casper, Wyo.....'24
Wood, James T., Jr., Associated Oil Co., 79 New Montgomery St., San Francisco, Calif.....'24
||Wood, J. Pendleton, Johannesburg, Calif.....'27
Wood, Robert H., 430 Tulsa Trust Bldg., Tulsa, Okla.....'20
Wood, Virgil O., 430 Tulsa Trust Bldg., Tulsa, Okla.....'20
Woodford, Alfred O., Pomona College, Claremont, Calif.....'24
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||Woodward, George E., Jr., Drawer F, Houston, Tex.....'29
||Woolfolk, Edward R., 703 Empire Bldg., Bartlesville, Okla.....'28
||Woolley, Glen C., Derby Oil Co., Wichita, Kan.....'28
Woolnough, W. G., Dept. of Home Affairs, Canberra, F. C. T., Australia.....'29
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Woods, Sam H., Box 296, Ardmore, Okla.....'25
Woodward, Harold Robinson, Box 1103, Wichita, Kan.....'25
Woolsey, E. V., Box 360, Luling, Tex.....'20
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Wright, Harry F., Box 1993, Tulsa, Okla.....'17
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Wyllie, B. K. N., Anglo Persian Oil Co., Britannic House, Finsbury Circus, London, E. C. 2, England.....'27
Wyman, Everett A., Amerada Petroleum Corp., Ardmore, Okla.....'24
||Wynn, Warren H., Box 859, Shawnee, Okla.....'26

Yager, Charles E., Box 1868, Fort Worth, Tex.....'24
||Yeager, Lloyd I., Empire Companies, Geological Dept., Bartlesville, Okla.....'26
Yewell, P. R., Box 853, San Angelo, Tex.....'26
Yoakam, Coler A., 1901 Exchange Natl. Bank Bldg., Tulsa, Okla.....'22
||Yoakam, Harlan H., Box 253, Chandler, Okla.....'29
||Young, Claude T., 410 S. Church St., Cordell, Okla.....'27
Young, E. J., 1110 Standard Oil Bldg., San Francisco, Calif.....'23
||Young, Gerald D., 703 Masonic Bldg., Bartlesville, Okla.....'29
||Young, Jackson S., Box 127, Fondren, Miss.....'28
||Young, Karl E., Union Sulphur Co., Sulphur, La.....'26

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Ziebold, William O., 1572 Virginia St., Charleston, W. Va.....'29
Zimmerman, James Z., Delmont, Westmoreland Co., Pa.....'22
Zoller, H. E., Shell Petroleum Corp., Pampa, Tex.....'25
Zoller, Lawrence J., Central Commercial Oil Co., Box 1928, Tulsa, Okla.....'21
Zorichak, Joseph J., 113 N. Beech St., Casper, Wyo.....'24

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# AT HOME AND ABROAD

J. W. STEELE, of Casper, Wyoming, has resigned as supervisor of the Mineral Leasing Division of the United States Geological Survey, Department of the Interior, and will go to Portuguese West Africa to take charge of exploration work in the province of Angola for the Sinclair Exploration Company.

SIDNEY POWERS, chief consulting geologist for the Amerada Petroleum Corporation, Tulsa, Oklahoma, spoke to the Tulsa Geological Society on January 20 on the topic of "Buried Hills."

RICHARD A. JONES, geologist, of Pearsall, Texas, has an article entitled "Production Below 5,000 Feet in 17 Gulf Coast Fields," in the January 24 issue of the *Oil Weekly*.

RAY V. HENNEN, consulting geologist for Transcontinental Oil Company, has opened offices at 501-503 Bank of Morgantown Building, Morgantown, West Virginia.

LOUIS ROARK, formerly with the Red Bank Oil Company, Tulsa, Oklahoma, resigned effective January 2. He is engaged in consulting work in geology.

G. R. HENSON, chief petroleum engineer of the Kansas, Oklahoma, and Panhandle division of the Shell Petroleum Corporation, has gone to The Hague, Netherlands, to consult with Shell officials on production problems.

WILLIAM J. MILLARD, geologist for The Texas Company in Colombia, returned to New York because of the recent decision of the Supreme Court of Colombia adverse to petroleum interests.

J. E. UPP is a micropaleontologist for The Pure Oil Company at Tulsa, Oklahoma.

HAROLD S. THOMAS, recently micropaleontologist for the Tidal Oil Company, has accepted a similar position with T. B. Slick, Inc., at Oklahoma City.

H. B. GOODRICH, petroleum geologist engineer of Tulsa, Oklahoma, spent part of January in California on business.

DAVID DONOGHUE, of the Tidal Oil Company, has recovered from a recent illness at Fort Worth, Texas.

OLIVER B. HOPKINS, chief geologist of the Imperial Oil Company, Toronto, Canada, was on his annual trip to South America last February.

JERRY B. NEWBY has been working in East Texas for FRANK BUTTRAM.

L. B. SNIDER is with the Producers and Refiners Corporation at San Antonio, Texas.

JOHN W. MERRITT and FRANK C. WIEST announce the removal of their office to 403-404 Springer Building, Sixth Street and Cincinnati Avenue, Tulsa, Oklahoma.

BURTON HARTLEY has moved from Cisco to San Antonio, Texas, and has opened an office at 1618 Smith-Young Tower, representing the Venezuelan-Mexican Oil Company.

LEON RUSS, of Dallas, Texas, is vice-president of the Petroleum Finance Corporation of Texas.

R. A. JONES is living at Pearsall, Texas.

E. A. WYMAN is geologist for the Amerada Petroleum Corporation at Wichita, Kansas.

JOE PALMER, consulting geologist, 737 Milam Building, San Antonio, is organizing the Pan American Aero Corporation to manufacture a light trimotor airplane to fly at slow speed near the ground for geological observation.

HARVE LOOMIS, of Abilene, Texas, is returning from a professional trip to Java.

HOWARD S. BRYANT, formerly assistant to the chief geologist of the Skelly Oil Company in Tulsa, Oklahoma, is now head of the geological department of the Skelly Oil Company in Kansas, with offices on the fifth floor of the new Ellis-Singleton Building in Wichita, Kansas.

WALLACE C. THOMPSON, of the Sun Oil Company, has recently been transferred from Wichita Falls to Tyler, Texas, to take charge of the company's geological work in East Texas.

REGINALD G. RYAN has accepted a position as geologist for the Louisiana Oil Refining Corporation and is to be stationed at Tyler, Texas.

R. A. MOORE, geologist for the Ramsey interests of Oklahoma City, has been working in Florida.

E. W. AMES, consulting geologist of Cisco, has moved to San Antonio, Texas.

E. W. KRAMPERT is now resident geologist for the Prairie Oil and Gas Company in Mississippi and Alabama with headquarters in Meridian, Mississippi.

W. I. INGHAM, formerly of Golden, Colorado, is now connected with the geological department of the Skelly Oil Company, Oklahoma City, Oklahoma.

W. R. CALVERT is in charge of the geological and land departments of the Grayburg Oil Company of San Antonio, Texas.

ALFRED CUMMING, consulting geologist, is living at the Ketchum Hotel, Tulsa, Oklahoma.

NILES B. WINTER is in charge of subsurface work for the Atlantic Oil Producing Company at San Angelo, Texas.

D. B. MYERS, of the Union Oil Company of California, at Los Angeles, has been placed in charge of oil land leasing as well as geology.

ED. W. OWEN represents the Wentz Oil Corporation at San Antonio, Texas.

EDWIN B. HOPKINS, consulting geologist of New York City, made a recent trip through the Mid-Continent to inspect the properties of the Petroleum Finance Corporation.

E. H. SELLARDS, associate director of the Bureau of Economic Geology, Austin, Texas, has secured a hand-made image carved in a block of sandstone weighing 75 pounds, which was discovered 16 feet below the surface in a gravel pit near Malakoff, Henderson County, Texas. The image represents a human head.

C. V. MILLIKAN has been elected chairman of the Petroleum Division of the American Institute of Mining and Metallurgical Engineers. Mr. Millikan is petroleum technologist for the Amerada Petroleum Corporation, Tulsa, Oklahoma.

HAL P. BYBEE is geologist for the Board for Lease of University Land Surveys of the University of Texas, with offices in the Western Reserve Building, San Angelo, Texas.

F. F. HINTZE is associate professor of geology at the University of Utah, Salt Lake City.

NORBERT GELLA gave an illustrated lecture Friday evening, January 31, before the Houston Geological Society, on the subject, "A Treatise on Geophysical Research Methods." At the luncheon on February 4, FRED P. SHAYES was on the program for a talk on "The History of the Refugio Oil Field."

GEORGE STEINER, consulting geophysicist of Houston, Texas, who handles torsion balances, has recently incorporated and is opening an office at Los Angeles, California, in the Petroleum Securities Building, in charge of H. W. ROSE.

J. E. ELLIOTT, president; F. C. MERRITT, vice-president; and H. W. PARMELEE, secretary, of the Rotary Process Refining Company, Los Angeles, California, expect to be refining oil by a new process by June 1.

FRED E. WOOD, production engineer for the Midwest Refining Company, Casper, Wyoming, has an article on "Observations on Well Spacing in the Salt Creek Field, Wyoming," in the January 22 issue of *National Petroleum News*.

B. L. LAIRD, of Dallas, Texas, for the past four years superintendent of the land and lease department of the Texas-New Mexico division of the Cal-

ifornia Company, has been transferred to the secretarial office of the Standard Oil Company of California, with headquarters at San Francisco.

R. J. RIGGS and W. L. DAY are in charge of the new offices of the Indian Territory Illuminating Oil Company and Delmar Oil Company in the Milam Building, San Antonio, Texas.

*Economic Geology*, beginning with the January-February issue, celebrates its 25th anniversary by becoming the official bulletin of the Society of Economic Geologists, furnished each member of the society. ALAN MARA BATEMAN, of Yale University, is editor, and WILLIAM SHIRLEY BAYLEY, of the University of Illinois, is business manager.

The Society of Economic Geologists recently elected officers for 1930-31 as follows: president, S. H. BALL; vice-president, ALAN BATEMAN; new councilors, E. C. ANDREWS, T. M. BRODERICK, and W. T. THOM, JR. The secretary is EDWARD SAMPSON, Princeton, New Jersey, and the treasurer is C.A.FISHER.

V. P. PENTEGOFF has accepted a position as geologist with the International Geophysical Company, Ltd., of Los Angeles, California.

G. R. ELLIOTT, petroleum engineer, Department of the Interior, Calgary, Alberta, Canada, wrote on "Drilling Speeds in Turner Valley," in the December, 1929, number of the *Canadian Mining and Metallurgical Bulletin*, the article being part of the *Transactions of the Canadian Institute of Mining and Metallurgy for 1929*.

R. A. STEINMAYER of Tulane University, New Orleans, Louisiana, has recently been promoted to the rank of captain and specialist in geology in the Staff Specialist branch of the U. S. Army Reserves.

At the regular meeting of the Tulsa Geological Society, February 3, FRANK C. GREENE gave a talk on "The Correlation of the Carboniferous Rocks of the Ardmore and Ouachita Sections," and FRANK R. CLARK spoke on "Lateral Gradation in Rocks of Cretaceous Age."

DEWITT T. RING, formerly of El Dorado, Arkansas, is geologist for the Ohio Fuel Gas Company, Columbus, Ohio.

GEO. EDWIN DORSEY, chief geologist of the Magnolia Petroleum Company of Dallas, Texas, spent February in New York City at the office of the Standard Oil Company of New York.

RALPH D. REED is chief geologist for The Texas Company in California with headquarters in The Texas Company Building in Los Angeles.

RICHARD A. CONKLING, consulting geologist of Oklahoma City, Oklahoma, is working in central-west Texas.

BEN H. PARKER represents E. W. Marland, Inc., at Oklahoma City, with an office at 423 East 10th Street.

A. W. MCCOY, vice-president of E. W. Marland, Inc., Ponca City, Oklahoma, addressed the Oklahoma City Geological Society in February on the subject, "The Origin of Oil Structures."

The San Antonio Section held its usual monthly dinner on February 3. Following the dinner, NORBERT GELLA gave a very interesting talk on "An Electrical Method for Prospecting for Oil."

GEORGE W. PIRTLE, a member of the firm of Hudnall and Pirtle, Coleman, Texas, is now located at Muskegon, Michigan, where he expects to spend several months.

C. A. YOAKAM, formerly chief geologist for the Sinclair Oil and Gas Company in the Oklahoma and Kansas District, is now vice-president and director of the Tri-State Royalty Company at Tulsa.

F. A. BUSH is chief geologist for the Oklahoma and Kansas district of the Sinclair Oil and Gas Company at Tulsa, Oklahoma.

L. C. DECIUS, recently chief geologist of the Associated Oil Company, California, has been appointed manager of the land department.

J. W. CLARK has resigned from the geological department of the Amerada Petroleum Corporation at San Antonio to take charge of the geological work of the Vacuum Oil Company in East Texas.

C. R. THOMAS is located in Tulsa, Oklahoma, as president of the Commerce Royalty Company, Inc., Masonic Building.

F. G. CLAPP, who has been in Europe and Asia during the past two years, has returned to the United States. He is at the Tudor Arms, Pondfield Road, W., Bronxville, New York. His consulting office is 50 Church Street, New York City.

WILLIAM A. WATKINS, of the Standard Oil Company, has been promoted from geologist to field superintendent for the Plaza Huincul region, Argentina.

H. G. SCHNEIDER, who has had charge of the land and geological departments of the Dixie Oil Company, is now vice-president. He is located at Tulsa, Oklahoma.

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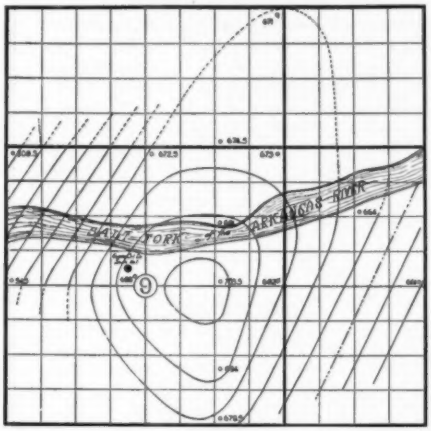


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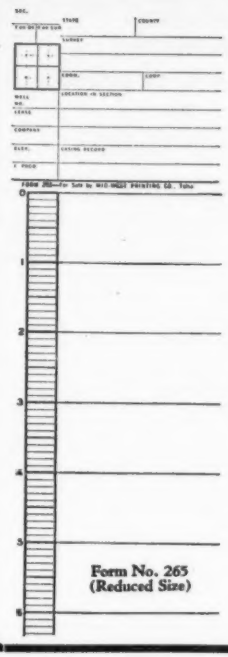

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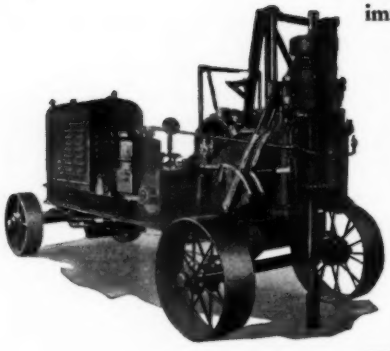

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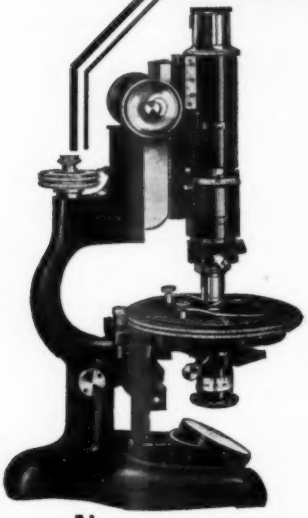

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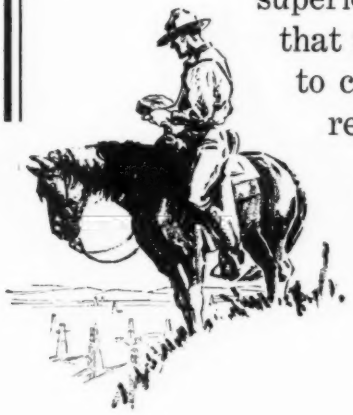

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